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AN

ESSAY

ON

FIRE.

TO WHICH IS ADDED, AN

APPENDIX.

By C. R. HOPSON, M. D.

Adde etiam qui conduplicant primordia rerum,
Aëra jungentes igni terramque liquori;
Et qui quatuor ex rebus posse omnia rentur,
Ex igni, terra, atque anima procrescere, & imbri.

—— —— —— —— Ignis, terræque coire
Corpus, & aërias auras, roremque liquorum,
Nil in concilio naturam ut mutet eorum.

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PREFACE.

THE doctrine of fire has in all ages engaged the attention of thoſe, who devoted themſelves to the ſtudy of nature; but was never developed with any ſucceſs, till the father of philoſophical chemiſtry, by a happy abſtraction, invented the term *Phlogiſton*, which he ſubſtituted in the place of the ſulphureous or oily principle of his predeceſſors: and though he was miſtaken in ſuppoſing the archetype of his idea to be a ſimple ſubſtance, yet by the introduction of this ſingle word into the philoſophical vocabulary, he has doubtleſs, contributed more to the advancement of natural knowledge, if we except the illuſtrious author of the Syſtem of Attraction,

than any other philoſopher, ancient or modern.

Succeeding theoriſts could do no better than tread in his foot-ſteps; and the writer of the following pages, when called upon in the year 1767, by the univerſity of Leyden, for the diſſertation uſually expected from the candidates for medical degrees, having choſen *fire* for his theme, had accordingly adopted this idea of Stahl, in its full extent; excepting that, having never been able to digeſt the doctrine of either phlogiſton, or any other matter producing fire, by being thrown into certain vibratory motions; and being convinced by a general, though accurate ſurvey, of the operations of nature, that either the air or an acid was always concerned in the generation of actual fire; and ſuppoſing withal, on the authority of the greateſt chemiſts, that the air itſelf was of an acid nature; he thought himſelf juſtified in aſſerting, that fire was nothing

nothing more, nor leſs, than a combination of acid with phlogiſton.

The little tract containing this hypotheſis is now reprinted in the Appendix to the following Eſſay, not certainly on account of the hypotheſis itſelf, becauſe the author was ſoon after its publication convinced, by the immortal diſcoveries of Dr. Black on the nature of fixable air, that the air of the atmoſphere never contained an acid otherwiſe than accidentally; and conſequently, that his ſyſtem was deficient in point of proof: but on account of its containing a *nominal* definition of fire, which has ſince been ſtrenuouſly inſiſted on by two very recent writers, and is in fact, the fundamental idea, that pervades their reſpective works. One of theſe gentlemen indeed, Mr. Scheele, has made very near approaches to the hypothetical part of the above-mentioned treatiſe, in aſſerting, that fire is a combination of air and phlogiſton; but although this treatiſe ſoon after its pub-

lication in the form of an inaugural diſſertation, was diſtributed pretty largely among the learned in different parts or Germany, and in ſome parts of Holland and France, yet the author is ſo far from imagining either of theſe ingenious writers to have ſeen his work, that he rather wonders, that neither of theſe ideas had before occurred to preceding ſyſtematics; nothing ſeeming to him more obvious, notwithſtanding the avowed falſity of the *genetical* definition, than the ideas, on which both theſe definitions are founded.

As for the other writer, M. Marat, he has not only adopted the idea of light and heat, jointly and ſolely conſtituting fire; but has even gone ſo far as to imagine, that he has rendered heat viſible. Heat, however, is an object of a very different ſenſe from that of viſion; and what he exhibits in his experiments as the matter of heat, ſeems to be nothing more, than that part of the vapour of burning bodies, which by com-

commixture with the air, is attenuated ſufficiently to admit the rays of light to paſs through it in greater quantity, than they do through the ignited and denſer part of the flame. The peculiarly bright ſpeck about the wick juſt in the centre of the flame, (when the experiment is made with a candle or lamp) is in like manner eaſily accounted for, on the ſuppoſition of the vapour being in that ſpot ſo much rarefied by the extreme heat, as to approach very nearly to a vacuum; and conſequently, to tranſmit the ſolar rays with almoſt the ſame facility as would be done by a real vacuum. That this is the true explication of the phenomenon, any one may readily be convinced, by meaſuring the image of the flame with a pair of compaſſes; and if farther demonſtration be wanting, an experiment communicated to the author by Mr. More, Secretary of the Society for the Encouragement of Arts, may be eaſily made, and it is preſumed, will throw more light on this

ſubject. It is this; let two lighted candles be placed 19 or 20 feet from each other; then ſeating yourſelf at the diſtance of 2 or 3 feet from one of them, look ſtedfaſtly through the flame of the near one, and the diſtant candle will be ſeen much diminiſhed in ſize through that part of the flame, which is not higher than the wick; but cannot be ſeen at all through the upper part, neither is it in the leaſt viſible, when the candles are placed at a much leſs diſtance from each other. This ſhews, that the rays of light proceeding from the ſecond candle are refracted through the external part only of the flame of the firſt; or in other words, through the blue flame of combuſtion, which is tranſparent: for as to the internal part it is quite opaque, and does not burn; a truth, which is fully proved by the experiments of Dr. Hooke, in a ſmall, but very ſcarce tract of his, entitled *Lampas*. In this tract the reader will find with ſurprize, many diſcoveries, generally

generally ſuppoſed to belong to more recent writers, and particularly the experiment above alluded to, of M. Marat; which is here very accurately deſcribed and delineated, and much more rationally accounted for, than it has been ſince by the French philoſopher.

The theory offered to the public in the following eſſay, although it was conceived ſo early as the year 1768, was never communicated, or at leaſt very indiſtinctly, to any one; till in the ſummer of 1777, the author imparted it to his friend, James Price, Eſq; of Guildford, (a young gentleman of acknowledged abilities in every department of chemiſtry and phyſics) pretty nearly in the ſtate, in which it is now preſented to the world; excepting that part of the ſyſtem, which reſpects the generation of heat, together with that which accounts for the detonation of nitre and other exploſive ſubſtances. This latter indeed could not, any more than the theory of

combuſtion, be brought to any tolerable degree of perfection, while the author remained ignorant of the writings of Scheele, Bayen, and Fordyce; with which, however, he did not become acquainted till the preceding ſummer. The chapter on the communication of heat, containing ſome ſtrictures on Dr. Crawford's theory, was, long before the publication of either Mr. Morgan's tract, or that of Mr. Magellan, "ſur "la Nouvelle Theorie du Feu," put into the hands of Mr. Cole, an ingenious mathematician of this place, advantageouſly known to the world by his "Conjectures on light "and comets;" and was likewiſe about the ſame time peruſed by the gentleman, to whom the author is obliged for the ſhort but maſterly expoſition of the different theories of fire; which, although written merely to fill up an idle hour, yet, as it may ſerve to elucidate this work, and ſupply ſome of its other deficiencies, is inſerted in the Appendix.

As

As the ſubject of the following pages has engaged the attention of philoſophers in a particular manner for ſome years paſt, the author, ſolicitous to avoid the charge of plagiariſm, has endeavoured to obviate it by the preceding ſhort account of the progreſs of this work. With the ſame view, and no other, has he reprinted *verbatim & literatim*, a tract abounding in errors. Theſe, it is hoped, the indulgent reader will excuſe, and place partly to the account of the imperfect ſtate in which many parts of philoſophical chemiſtry were at the time, when the tract was firſt publiſhed, but ſtill more to the account of the author himſelf, as being at that time in his novitiate.

It will perhaps be but too obvious to the learned Reader, that the author is as yet a ſtranger to the works of the illuſtrious philoſophers, Bergman and Fontana, otherwiſe than through the medium of journals and extracts. Any deficiencies ariſing

ing from this and other cauſes,—he will endeavour to ſupply in a future work, the materials for which have long lain by him, and which he purpoſes to publiſh ſome time next winter, under the title of "The "Primary Properties of Bodies defined, "with Remarks and Obſervations tending "to illuſtrate the Principles of Philoſo-"phical Chemiſtry."

COLCHESTER,
May 16, 1781.

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APPENDIX.

Of LIGHT, HEAT, *and* FIRE i

Tentamen de TRIBUS IN UNO i

ERRATA.

Page 11. Line 6. dele *both*.
—— —— l. 7. for *may produce*, read, *may likewiſe produce*.
—— 23. l. 9. for *undubitably*, r. *indubitably*.
—— 29. l. 9. for *in*, r. *is the*.
—— 39. l. 3. and 4. bottom, r. *permanently elaſtic*.
—— 40. from No. 1. 5. 6. 7. 10. dele *by means of air*.
—— 43. l. 7. from bottom, for *extracting*, r. *extricating*.
—— 44. l. 9. dele *the*.
—— 46. l. 12. dele *then*.
—— 49. l. 8. from bottom, for *page* 30. r. *page* 46.
—— —— —— *ſeemed*, r. *ſeems*.
—— 57. l. 10. from bottom, r. *and* linſeed-oil *varniſh*.
—— 62. l. 16. for *to*, r. *too*.
—— —— l. ult. for *ſulhpur*, r. *ſulphur*.

In the APPENDIX.

Page 8. l. ult. for *hac*, read, *in hac*.
—— —— l. 10. for *hi*, r. *hæ*.
—— —— —— for *unum*, r. *unam*.
—— —— —— for *ſit*, r. *ſit*.
—— 11. l. ult. for *treibendo*, r. *treibende*.
—— 13. l. 22. for *abſonem*, r. *abſonum*.
—— 14. l. 7. from bottom, for *heterogeniis*, r. *heterogeneis*.
—— —— l. 3. from bottom, for *hoc*, r. *ineſſe*.
—— 15. l. 8. from bottom, for *hoc*, r. *hac*.
—— 16. l. 20. for *ſolis*, r. *ſolis*.
—— —— —— before *excipias*, r. *ſi*
—— 18. l. penult. r. *evolutam materiam*.
—— 19. l. 10. from bottom, after *ſulphuris*, r. *& ferri*.
—— 21. l. 3. for *qui*, r. *quem*.
—— 25. l. penult. for *le*, r. *la*.
—— 32. l. ante penult. for *ſervat*, r. *ſervat*:

AN ESSAY ON FIRE.

CHAP. I.

Definition of the word FIRE.

IN an enquiry into the nature of fire, it may be worth while previouſly to ſettle the meaning of the term itſelf; which, having been almoſt always conſidered, as ſuggeſting merely a ſimple idea, (although in reality it conveys a complex one, as repreſenting more than one impreſſion) has accordingly created the greateſt confuſion, at the very firſt outſet, in moſt, if not all the treatiſes written on this ſubject.

In order to avoid this error, the beſt method we can take, will be, quitting the la-

byrinths of metaphyſics and the ſchools of the philoſophers, to conſult upon this matter our own feelings, and the univerſal and uniform notions of the untaught, and therefore unprejudiced part of mankind.

From the collated teſtimonies of the latter, it will appear, that the phenomena of light and heat being generally united in one body, have in all ages and nations been uniformly joined in one idea under the appellation of *fire*.

By attending to our own feelings and experience, we ſhall find, that when we have had the ſenſation of heat, we have commonly (though not always) diſcovered it to have proceeded ultimately from a luminous body. At leaſt our experience of this fact has been ſo general, that (except in a few well-known inſtances) whenever we ſee light, we are uſed to expect the ſenſation of heat to accompany it; although in theſe expectations we are liable, in ſome caſes, to be diſappointed. But, when the ſenſations of light and heat apparently proceed from the ſame object, we then uniformly and without heſitation pronounce that body to emit or contain

fire;

fire; by this name deſigning, not the cauſe, but the actual conjunction of theſe ſenſations or phenomena.

Thus far the uninſtructed vulgar, whoſe language is ſimple and intelligible, becauſe little ſolicitous about generalizing their ideas, they ſpeak from their feelings, and think without regard to ſyſtem. Very different are the views, and conſequently the language of philoſophers. Theſe, in their endeavours to ſimplify the operations of nature, have too prematurely taken for granted the exiſtence of a ſubſtance, which, according to its different modifications, is capable of exciting ſeparately either the ſenſation of light, or that of heat, in the human frame. To this imaginary ſubſtance they have given the name of *fire*; although it be ſuppoſed by them, not unfrequently to exhibit one only of thoſe phenomena, both of which, in the popular apprehenſion of the word, muſt neceſſarily be preſent at the ſame inſtant of time, in order to ſuggeſt to us the idea of fire.

The error then of philoſophers lies in this: that having ſeen the phenomena of light and

heat proceeding from the ſame body, they have raſhly ſuppoſed light and heat themſelves to be, not ſeparate bodies, but one and the ſame fluid: ſo that, by applying the idea of unity, which belongs to the ignited body, to the matters iſſuing from it, they have imperceptibly made a very illogical tranſition from the concrete to the abſtract, from the containing to the contained.

Neither does the confuſion terminate here: but as this error appears to be in ſome meaſure the ſource of all the reſt, it ſeemed neceſſary to pay ſome attention to the inveſtigation of its cauſe; though at the ſame time we ſhall be obliged to paſs over in ſilence, others equally important, which are frequently to be met with in authors upon this topic; or at beſt muſt content ourſelves with making only occaſional mention of them; they being too numerous, as well as too intricate, to admit of being diſcuſſed in a treatiſe, intended rather to propoſe new opinions than to canvaſs the old; and rather to furniſh hints for improving the doctrine of fire, than to give a digeſt of what has been already done upon this ſubject.

CHAP.

CHAP. II.

LIGHT *fixed in Bodies, a conſtituent Part of* PHLOGISTON.

WE ſhall therefore proceed immediately to conſider fire in a different poinſt of view, *viz.* as it is fixed in and conſtitutes part of other bodies, in which ſtate it is generally known by the name of *phlogiſton*. Here again we have before us an ample field for diſcuſſion: but for the reaſons juſt mentioned, we ſhall drop all controverſy on this head, and barely preſent the reader with our own conceptions of the matter; in hopes that (when it is taken in the light in which we ſhall repreſent it) the difficulties commonly attending the doctrine of phlogiſton may vaniſh; and particularly that the objections which have been repeatedly urged againſt it, with ſo much ſpecioufneſs, and indeed (with reſpect to the doctrine generally promulgated) with ſo much juſtice, will appear to have been made without any foundation.

Fire then, according to the idea we have given of it, being a compound of light and heat, can have no title to be conſidered as an element, although theſe its component parts may very juſtly claim that diſtinction. Now, as we ſuppoſe, and ſhall endeavour to ſhew, that phlogiſton is nothing but fire fixed in bodies, whatever has been ſaid by chemiſts, ancient and modern, about the ſimplicity of phlogiſton, or the principle of inflammability, falls to the ground; and this being ſubverted, the many objections which have been juſtly raiſed againſt this pretended element, fall with it; and the inflammable or ſulphureous principle, or by whatever other name it may be called, by the loſs of a fictitious title, will gain the more ſolid advantages of having its other properties more firmly eſtabliſhed, and of being much more univerſally and clearly comprehended.

Chemiſts have been hitherto liable to be perpetually teized (not to ſay inſulted) by the impertinent demands, as well of philoſophers, as of others, who pretended to little more than plain common ſenſe, to have a ſight of this their favourite and omnipotent phlogiſton, uncombined with any other ſubſtance,

ſtance, or at leaſt to have it in that ſtate manifeſted to ſome one or other of their ſenſes *. A proper attention to the phenomena of fire would have enabled them to ſatisfy theſe troubleſome queriſts, by convincing them, that as the light they ſaw, and the heat they felt, proceeded from the combuſtible body in the act of combuſtion, and as

* Were what is called the principle of inflammability merely a principle, it might be ſuppoſed to conſiſt in a peculiar arrangement of parts: but as it is known to be transferable from one body to another, ſuch a ſuppoſition would create unconquerable difficulties. For which reaſon the chemiſts have been obliged to acknowledge phlogiſton to be a ſubſtance. But if it be really a ſubſtance, where is the unreaſonableneſs of the expectation, that this ſubſtance might be collected and rendered ſenſible? as M. Macquer expreſſes it. For allowing it to be of ſo ſubtle a nature, as inſtantly to penetrate the glaſs-veſſels in which it is ſeparated by combuſtion from the inflammable body; being now (by the hypotheſis) perfectly detached and freed from all other matter, it muſt certainly, after having made its eſcape through the pores of the veſſel, which contained it in its combined ſtate, manifeſt itſelf by ſome means or other to our ſenſes. This, however, is not ſuppoſed to happen. What then is this matter, which has none of the properties of matter? or what this ſubſtance without ſenſible qualities?

the ſame body after undergoing that proceſs is no longer combuſtible, both the light and the heat muſt have neceſſarily pre-exiſted in the body; and farther, as this matter, which gives combuſtibility to the body, being transferred to an incombuſtible body, communicates to this alſo the property of giving out light and heat in the ſame circumſtances, it is evident, that phlogiſton, or the principle of inflammability, is nothing more than the conjunction of the matters of light and heat fixed in bodies; and that the only method of exhibiting phlogiſton in its original purity, and ſeparate from all other matter, is to produce a body in the act of combuſtion, by which operation the light and heat, of which both fire and phlogiſton conſiſt, are ſeparated from the body, perfectly free from any heterogeneous ſubſtance whatever.

It is true, there are ſome philoſophers who chuſe to deny the ſeparation of light from the burning body; becauſe they can account for its origin in a different manner. But till they have proved the truth of their complicated theories, the ſuperior ſimplicity of this will be ſufficient to procure it credit with the

the unprejudiced part of mankind. Add to this the internal evidence it carries with it, and that in all hypotheſes, in which fire is not acknowledged as the chief conſtituent part of the inflammable principle, this ſupernumerary element has occaſioned much trouble to their reſpective authors; who at length not being able to ſay, what it is, have been obliged to content themſelves with telling us, what it is not.

One of theſe ſyſtems, in which phlogiſton is ſuppoſed by its vibrations to put in motion the light exiſting throughout all ſpace, has not the advantage of being generally underſtood; beſides, that it evidently depends on an hypotheſis ſo often exploded, that it would be ſuperfluous to take notice of it here. Another lately publiſhed by Mr. Scheele of Upſal, ſuppoſes both the light and the heat ariſing from the combuſtion of bodies, to be compounded (though in different proportions) of the phlogiſton of the body, and of a portion of the air, that comes into contact with the body previouſly rubbed or otherwiſe heated. But this account of the origin of fire, though perhaps it be nearer the truth than

than any other yet publiſhed, is much too complex to be admitted as a true interpretation of the operations of nature, which are always effected by the moſt ſimple means. And though it be an undoubted truth, that actual fire, or the conjunction of heat with light, is never produced without the intervention of air; yet we know, that heat alone is often generated by mere percuſſion or friction in ſpaces entirely void of air. The ſame may be ſaid of light, of which we have an inſtance in the mercurial barometer; for notwithſtanding that this light be now generally, and indeed with great juſtice, attributed to electricity, ſtill, however, it is light, and light produced without the ſmalleſt particle of air intervening.

From theſe conſiderations it is very evident, that air cannot poſſibly enter into the compoſition either of heat or of light; and by a parity of reaſoning, the ſame may be proved of any other ſubſtance whatever. So that the ſimplicity and elementarity of both theſe bodies, ſeems eſtabliſhed on the firmeſt foundation.

CHAP.

CHAP. III.

HEAT *fixed in Bodies, a conſtituent Part of* PHLOGISTON.

WE therefore do not heſitate to aſſume as a principle, the exiſtence of light in a fixed ſtate in bodies, in which ſtate it contributes to form the *principle*, or (to ſpeak philoſophically) the material cauſe of inflammability. With regard to HEAT, the other conſtituent part of phlogiſton, we ſhall find the demonſtration of its preſence in bodies much more difficult; not only becauſe it is not ſuppoſed to exiſt in them in a quieſcent ſtate, but chiefly becauſe its very exiſtence as a ſubſtance, is denied by the greateſt authorities in the philoſophic world; and the moſt active of all ſubſtances, that which gives life and motion to the reſt, is degraded by them to the rank of a mere quality, and indeed is now generally conſidered only as a particular modification of univerſal matter.

Now, not to mention the variety of gratuitous ſuppoſitions the patrons of this doc-

trine

trine are obliged to make, in order to reconcile it to phenomena, we apprehend that (as they muſt of neceſſity acknowledge one particular matter better fitted than the reſt, both to undergo and communicate that vibratory motion, in which according to them, the eſſence of heat or fire conſiſts) they will find it a moſt difficult undertaking to account for this communication of vibrations, according to the eſtabliſhed laws of motion. And ſhould they ſucceed in this, they will find a ſtill harder taſk remain, which is, to inform us, what this peculiar matter is and whence it acquires the properties they have aſſigned to it.

It will not be ſufficient for them to anſwer, that ſuch matter exiſts, becauſe the properties they have attributed to it, are eaſily deducible from divers phenomena, more eſpecially thoſe of combuſtion. It is incumbent on them to prove, that there actually does exiſt a matter transferable from one body to another, and particularly capable of being thrown into certain vibratory motions, as well as of exciting them in any other ſubſtance, to which it may happen to be united.

So

So that we ſee, the mechanical philoſophers are at laſt reduced (if they would talk conſiſtently) to adopt the phlogiſton of the chemiſts, whoſe lax and licentious modes of reaſoning they have ever affected ſo much to deſpiſe; with this difference indeed, that the Spagyric philoſophers have conſtantly aſſerted the exiſtence of a peculiar matter, which, when ſeparated from all other heterogeneous bodies, produces either heat, or light, or both, according to the quantity in which, or the velocity with which it has been ſeparated; while the others conſtantly recurring to their favourite principles of motion, yet at length being obliged by incontrovertible facts, to acknowledge the exiſtence of this peculiar ſubſtance, have contented themſelves with allowing, that there is one part of matter more ſuſceptible of the igneous motion than the reſt; which however, are by no means excluded from their ſhare in this property. Thus heaping hypotheſis on hypotheſis, and explication on explication, they have involved a ſubject naturally clear and intelligible, in doubt and obſcurity; and by a premature attempt to reduce the whole ſyſtem of the univerſe to

firſt principles, have departed totally from the plain unaffected manner, and the unerring ſimplicity of nature.

We muſt not totally paſs over in ſilence the opinion of thoſe, who ſuppoſe heat to be a modification of the ſame matter, which, in other circumſtances and differently modified, produces the ſenſation of light. In anſwer to this (omitting arguments of inferior force) it may be ſufficient to obſerve, that there are many bodies, ſuch as luna cornea, and the precipitates of the perfect metals in general, the leaves of vegetating plants, &c. which, when expoſed to the light (eſpecially to the direct beams of the ſun) have a power of fixing the matter of light in their ſubſtance: although when expoſed to the action of mere heat, they do not become more phlogiſticated, than they were before ſuch expoſure. In ſhort, we muſt take the liberty of conſidering it as a ſufficient objection to all the theories of heat, deduced from the vibrations of matter, or the impulſe of light, that none of their reſpective authors have given themſelves the trouble of paſſing in review the principal phenomena, that preſent themſelves to us in

chemical

chemical operations, and of applying them as teſts to their different ſyſtems. Very few indeed of the ſupporters of the mechanical doctrine, have been capable of undertaking this taſk; and the few that have, have very prudently declined it. It is, however, to be lamented, that Mr. Macquer, whoſe inſtructive writings bear equal marks of candour, taſte, and judgment throughout, ſhould not have taken the pains of thus defending, in the moſt effectual manner, an opinion, to which he profeſſes himſelf a convert. The defenders of the oppoſite ſentiment, who have almoſt all of them been profeſſors of the *philoſophy by fire*, have ſeldom ſhrunk from this office. Among theſe, who in fact, are the only true judges of the point in diſpute, Mr. Scheele, the moſt recent of them that has hitherto come to our knowledge, ſtands the foremoſt, as having with unwearied induſtry, not only taken a very extenſive as well as accurate view of the moſt important facts, which are to be found in authors relative to this ſubject; but likewiſe as having by his very curious experiments, brought to light a great number of other facts equally

new

new and intereſting. With ſome of theſe we ſhall occaſionally enrich the following pages, as many of them tend, in a ſtriking manner, to confirm the doctrine here delivered; which perhaps would have appeared with ſtill more advantage, had we not been induced to delay the peruſal of this gentleman's treatiſe, till within a few weeks of the time we had allotted ourſelves for the publication of this performance.

Since therefore all other theories concerning the generation of heat, are evidently founded on falſe principles, or ſupported by illegitimate concluſions; we think ourſelves entitled to aſſert (at leaſt till it be diſproved by facts) the exiſtence of a matter, which when emancipated by percuſſion or otherwiſe from the bodies, to which it was united, is neceſſarily put in motion (for without motion there can be no action) and the effect of whoſe action upon the human frame, becomes a ſenſation, known by the name of heat. That the ſame cauſe produces according to certain determinate laws an expanſion and diſtention in all matter, whether animate or inanimate, is on all hands allowed; and although it be

perhaps

perhaps impoſſible to conceive how a mere communication of motion, ab extra, ſhould have this effect; yet we can very eaſily comprehend, that a ſubtle matter, entering into the pores of bodies may, and neceſſarily muſt (as long as it is in motion) both diſtend theſe, and produce in ſuch other ſubſtances, as are endued with a power of ſenſation, as well as of motion, a peculiar effect, which, when attended to by the mind, is immediately recognized by the name of heat.

If it be objected to this doctrine, that cold heat is a contradiction in terms, and that it is impoſſible for the imagination of man to conceive heat either cold or inactive. It may be replied, that though the ſenſation of heat cannot be cold, the matter of heat may; that is, the ſubſtance which in its active ſtate gives us that ſenſation, may, and neceſſarily muſt, ceaſe to act on us and all other extraneous bodies in its fixt and quieſcent ſtate; although it as neceſſarily re-acts on the particular body, by which it is attracted, and to which its action is confined. Beſides the fixation and conſequent quieſcence of fire in bodies, is a tenet almoſt univerſally held by philoſophers; now

cold fire is as abſurd and unintelligible an expreſſion, as cold heat; for without heat we ſhall find it difficult to conceive fire, at leaſt in its active ſtate. If, however, there be any who will not admit the poſſibility of fire lying dormant as it were, and inactive in bodies, ſuch may poſſibly be induced to deny alſo the fixation of air; and on the ſame principle, they may very plauſibly refuſe to believe the exiſtence of water in the ſtate of ice; for ice is not more evidently converted into water on the application of heat, than phlogiſton is into light and heat by combuſtion; which when the body containing phlogiſton has once undergone, no more light can be obtained from it, nor heat, except what may flow into it from the air or other contiguous ſubſtances.

Having thus eſtabliſhed, as we hope, on a firm foundation, the nature and conſtitution of thoſe two great agents in chemiſtry fire and phlogiſton, we ſhall hereafter confine the term *fire* to the conjunction of the *phenomena* of light and heat; and phlogiſton to the conjunction of thoſe *matters* in their quieſcent and inactive ſtate, when they are fixed in and

combined

combined with other groſſer and more palpable bodies.

Before we quit the ſubject of heat, we ſhall take this opportunity of conſidering certain affections of it, which, we apprehend, have been ſubjected to groſs miſrepreſentations, owing principally to the nature of phlogiſton not having been ſufficiently attended to. And firſt we ſhall deliver our ſentiments

CHAP. IV.

On the Communication of HEAT.

AN accurate attention to the phenomena of calefaction and refrigeration will convince us, that one ſubſtance communicates heat to another, in a proportion compounded *directly* of their reſpective conducting powers, and of the extent of ſurface in mutual contact; and likewiſe (if there be any other ſubſtance contiguous to the heating body) *inverſely* of the conducting power of that ſubſtance, together with that of the heating body, and of the extent of ſurface there in mutual contact.

But heat appears to be conducted by bodies in proportion: 1ſt, to their denſities, and 2dly, to the quantity of uncombined phlogiſton contained in them; this is evidently the caſe with metals, which ſooner receive and part with this fluid, than any other known ſubſtance. The reaſon ſeems to be, that the adventitious heat is not ſo immediately diſpoſed to unite with the earthy, or more ſolid parts of the metal, but rather with the light fixed in it, which being there rather in a ſtate of diffuſion or mixture than of combination, may be conſidered as in a manner heterogeneous or foreign to the metallic ſubſtance; and may conſequently be acted upon by this fluid ſeparately, without the other parts being much affected at firſt, till at length the heat is accumulated in ſo great quantity, as to act on the inert earth likewiſe.

As a teſt of the truth of the preceding obſervations, we ſhall endeavour to explain by them the famous experiment of Fahrenheit and Boerhaave, mentioned by the latter in his *Elements of Chemiſtry*, *P.* II. *Exper.* 20. *Cor-*

11. and by Dr. Crawford in his *Experiments and Obſervations on Animal Heat*, *page* 11.

If a pint of water of two hundred and twelve degrees of heat, be mixed with a pint of the ſame fluid at thirty-two, the temperature of the mixture will be one hundred and twenty-two, that is, half the ſum of the degrees of heat in both *.

But if a pint of water be mixed with a pint of mercury, and a greater degree of heat

* Boerhaave entirely miſtook Fahrenheit's meaning with reſpect to the reſult of this experiment, as Fahrenheit himſelf, who made the experiment for Boerhaave, complained to Profeſſor Gaubius. [See the French tranſlation of the Elements of Chemiſtry, by Profeſſor Allamand, l. c.] Or rather, the aukward and complex mode of expreſſing this reſult, ſeems to have led Boerhaave into an error with reſpect to the reſult itſelf. Whether this expreſſion was originally that of Fahrenheit, or Boerhaave's own, does not now appear; but both the reſult and expreſſion have been faithfully copied by ſucceeding writers. Boerhaave ſays, that the temperature after the mixture, will be equal to half the exceſs of heat in the hotter portion; *added to the degree of heat in the colder*, ſays his tranſlator, by way of correcting the error. But it is preſumed that the more ſimple expreſſion ſubſtituted above renders this addition, which rather adds to the intricacy and obſcurity of the ſentence than otherwiſe, quite needleſs.

be previouſly given to the water, than to the mercury, the heat of the mixture will conſtantly exceed the proportion above-mentioned.

If, on the contrary, the mercury be made hotter than the water, the temperature of the mixture will always fall ſhort of that proportion.

Now mercury being above fourteen times denſer than water, and containing beſides a conſiderable quantity of phlogiſton, which is not to be found in the latter, muſt neceſſarily (by the hypotheſis) poſſeſs a much greater conducting power. When, therefore, a thermometer is immerſed in a mixture of theſe fluids taken in equal bulks, if the water, when ſeparate, had the greater degree of heat, it will now communicate part of it very quickly to the mercury; becauſe this latter, by its ſuperior conducting power, will abſorb it very faſt; and in conſequence of the ſame power tranſmitting it likewiſe as faſt to the thermometer, this inſtrument muſt of neceſſity be much more expanded than when it is immerſed in a mixture of hot and cold water only.

Again,

Again, if (before the two fluids are mixed) the mercury be hotter than the water, the ſuperior tranſmitting power of the former will throw the heat on to the water faſter, than this latter fluid will be able to conduct it to the thermometer; becauſe mercury cools much faſter than water, as has been found by experiment, at the ſame time that water is indubitably much ſlower in acquiring heat. Hence we infer, that in our experiment, the ſtrong conducting power of the mercury *forces* (as it were) upon the water, a greater quantity of heat than it can eaſily tranſmit to the thermometer. In which caſe it is manifeſt, that the fluid included in this inſtrument, will at no one inſtant of time contain ſo much heat as in the inſtance before given, where the inſtrument is immerſed in water alone.

In the preceding explication, we have frequently made uſe of the terms *conducting* and *tranſmitting* power, and that ſometimes indifferently, in as much as we conceive the former to include the latter. However, as they differ from each other, as a part does from the whole, we have conſtantly taken care, when we have meant to expreſs the

whole of the force in queſtion, to call it the conducting, not the tranſmitting power; becauſe this latter epithet will not ſerve to give us an idea of that power exerciſed by bodies, by which they ſeem to attract, as well as to part with, the heat in contact with them; a power in every reſpect ſimilar to that, by which electricity is communicated, although neither of theſe forces can properly be called attractive.

We ſhall take another opportunity to ſhew, that the power which moſt bodies poſſeſs, of conducting electricity, depends on and is proportionate to the quantity of uncombined phlogiſton contained in them: for which reaſon metals make the beſt conductors, and after the vitreous earths, ſulphureous and reſinous ſubſtances, in which the inflammable principle is combined with an acid, conſtitute the worſt. At preſent we ſhall only obſerve, that in this point the two fluids, which preſent us with the different phenomena of heat and electricity, ſeem pretty exactly to agree, as may eaſily be collected from Dr. Crawford's very accurate experiments, merely by changing the expreſſion,

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and inverting the order of his concluſions. Thus, when that ingenious experimentaliſt calculates, that the abſolute heat of air is to that of water, as 18, 6 : 1; we are to underſtand, that ſetting aſide that which reſults from their different denſities, the power of air in conducting heat is to that of water, as 1 : 18, 6; which perhaps does not eſſentially differ from the proportion in which theſe fluids conduct the electric matter. Some of theſe experiments, indeed, appear to have been made in circumſtances, extremely unfavourable to accuracy or preciſion; ſuch as that upon fixed air for example, in which accordingly the power of conducting heat by no means correſponds with that which tranſmits electricity, when compared with the ſame powers in atmoſpherical air, taken as the ſtandard of proportion.

The experiments upon metals and their calces are likewiſe liable to the ſame objection. In ſhort, it ſeems, that in order to form a preciſe idea of the power, which ſerves to conduct heat in different ſubſtances, it is neceſſary that they ſhould be

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in a fluid ſtate, a condition which in moſt of them is wanting, and particularly in the metals, where it is to be found in mercury alone. The reaſon why they ſhould be fluid, is that they will be thus enabled to ſurround the thermometer, as the water does, which ſerves as the ſtandard of compariſon. Theſe ſubſtances ſhould alſo, generally ſpeaking, be immiſcible with water, that both fluids might be examined at the ſame time by the immerſion of the thermometer. However, after having found the conducting power of oil, many ſolid matters ſoluble in water, ſuch as ſalts and gums, as likewiſe thoſe which are ſoluble in ſpirits of wine, might be put to the teſt of the thermometer, by mixing the ſolutions of them with the above-mentioned fluid. Yet ſtill we ſhould only have the conducting power of the ſolutions, not of the ſolids themſelves. And with reſpect to the metals, it muſt be obſerved, that the preciſe degree of dephlogiſtication in their earths, is not determinable by any means hitherto diſcovered.

To all this we may add, that it does not ſeem poſſible to compare the powers of ſo-

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lids in conducting heat, with the like powers poſſeſſed by fluids, at leaſt not in the way propoſed by the gentleman above-mentioned. For if a thermometer be applied to a maſs of iron heated to a certain degree, and this iron be afterwards plunged into water colder than itſelf, the thermometer will receive, not the heat from the iron, but that only, which reſults in conſequence of the conducting power of the water. But this we have ſhewn above, to be very different from the degree of heat communicated from the iron to the water. If indeed the iron were fluid, we might then by this method be able to judge of its conducting power: becauſe the inſtrument would in that caſe be immerſed in the metal as well as in the water, and conſequently the heat would paſs to it as immediately from the former ſubſtance as from the latter.

CHAP.

CHAP. V.

On the Production of HEAT.

WE are now led, by the laws of method, to the inveſtigation of one of the moſt general phenomena of nature; a phenomenon which ſeems to have perplexed in ſome meaſure all, who have written on the ſubject of fire; as well thoſe, who, treating the matter chemically, have ſuppoſed heat to be a ſubſtance *ſui generis*, as thoſe who have conſidered it only as a modification of light or other matter. It is true, that the ſeeming ſimplicity of the doctrine delivered by the latter, in which the generation (as it is uſually ſtiled) of heat, is conſtantly referred to friction alone, has not only induced philoſophers in general to overlook the numerous facts which militate againſt it, but has even engaged the major part of chemiſts to acquieſce in it; although their favourite ſtudy will readily ſupply them with much more fruitful principles, as well as innumerable and unanſwerable

ſwerable objections to the prevailing hypotheſis.

'For, allowing that heat conſiſts in motion, and that this motion, (or if you will) theſe vibrations are cauſed by friction, what degree of friction can poſſibly exiſt between the ſoft and yielding particles of oil of turpentine and ſpirits of nitre, ſufficient to produce the inflammation of the oil? or between oil of vitriol and water? or between this latter and ſpirits of wine *? When it is notorious, that by homogeneous fluids, however rubbed or conquaſſated, either againſt each other, or againſt ſolids, not the ſmalleſt degree of ſen-

* But ſuppoſing, with the great ſupporters of the corpuſcular philoſophy, the particles of heterogeneous fluids to be poſſeſſed of the higheſt degree of hardneſs, it will ſtill be difficult to conceive, how the ſmall quantity of motion perceptible in effervеſcing mixtures, ſhould be able to produce by friction ſo violent a heat, as, we often ſee, in conſequence of making theſe mixtures. And, where heat is generated from non-effervеſcent mixtures, we ſhall be yet more at a loſs to account for its production on this principle; as we not only perceive with our ſenſes, but are likewiſe aſſured from the conſideration of the want of an elaſtic fluid peculiarly adapted to excite theſe inteſtine motions, that in ſuch caſes the motion, and conſequently the friction, is very inconſiderable.

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ſible heat is generated. But if the mutual friction or attrition of the particles of *homogeneous* fluids has not this effect, why ſhould we expect to find it in the commotion ariſing from the mixture of *heterogeneous* liquors?

We muſt therefore neceſſarily have recourſe to a different ſyſtem, and ſay with ſome reſpectable chemiſts, that heat exiſts ready formed in the interſtices, and (we may add) on the ſurfaces of bodies; and, inſtead of being *generated*, is only *extricated* from theſe bodies in the various circumſtances, in which we conſtantly ſee it produced. Now theſe circumſtances may be all comprehended in three grand claſſes, *viz.* 1. *Commenſtruation*, or chemical union. 2. *Percuſſion*; and 3. The *decompoſition of phlogiſton by the air*; and theſe again being collectively conſidered under one common point of view, gives us, for the proximate cauſe of heat, the extrication of this ſubſtance from the bodies, in which it not only virtually, but likewiſe materially before exiſted.

With reſpect to the firſt of theſe methods of exciting heat, we may obſerve, that ſome of theſe bodies, which generate heat by their mixture,

mixture, ſuch as *e. g.* oil of vitriol and water, or lime, when mixed with this fluid, either do not contain phlogiſton at all; or if they do, are found not to have parted with it during their commenſtruation. Whence we argue, that either heat exiſts in them in a ſtate of combination without the matter of light, and therefore without forming phlogiſton; or elſe it only adheres to their ſurfaces, and between their interſtices, being however attracted by them ſufficiently to be prevented from exerciſing its proper powers on other bodies. If the former ſuppoſition be true, then heat muſt enter the compoſition of the bodies above alluded to, and being once ſeparated from them, the bodies themſelves muſt be inevitably deſtroyed. But in the caſe of oil of vitriol being added to water, and an infinite number of analagous mixtures, this decompoſition or deſtruction does not take place: we are therefore obliged to admit the latter hypotheſis, and it only remains to ſhew, how the extrication is performed.

This will be beſt explained by another obſervation, *viz.* that (excepting where the air is phlogiſticated) whenever heat is generated

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in the commenſtruation of bodies, thoſe bodies apparently penetrate each other; the ſum of their ſpecific gravities being conſtantly and uniformly found on ſuch occaſions, to have increaſed. We likewiſe find, that this extrication of the heat from bodies by commenſtruation, is ſo far from deſtroying or decompoſing them, that it does not even induce the leaſt change in them; for, on being ſeparated again from each other by diſtillation or other proper methods, they appear to poſſeſs the ſame properties in every reſpect, as they were endued with before the mixture was made.

Having accounted for the extrication of heat on the principles of, what is generally termed, chemical attraction, we ſhall now endeavour to point out the connexion ſubſiſting between this and our ſecond diviſion, which, as including *friction*, we ſhall here treat of under the more general name of *percuſſion*. For, ſince all friction may be conſidered as conſiſting of a number of percuſſions following each other with extreme velocity, what is ſaid of the one will eaſily apply to the other. Now we know, that bodies are not to be brought into contact with each other, but by a certain

degree

degree of preſſure. But when two bodies are in mutual contact, they muſt neceſſarily be within the ſpheres of each others attraction; and conſequently any ſubſtance before adhering to their ſurfaces, will be liberated from the attractive power, by which it was held there, by the ſuperior, though perhaps momentary, attraction of ſuch bodies to each other. Thus, if the matter of heat be ſuppoſed to adhere to the ſurfaces of bodies, it will, by the mutual attraction of theſe bodies, when preſſed together, be immediately extricated from them, and converted into active and ſenſible heat. When indeed the preſſure is made ſlowly, the heat will fly off, and expand itſelf in the neighbouring bodies, ſo as not to become ſenſible either to our feelings, or by means of the moſt accurate inſtruments hitherto diſcovered. But when the preſſure is made ſo quickly, as to deſerve the name of percuſſion, and the ſtrokes are frequently repeated, the heat is commonly generated in ſufficient quantity to be perceived by our ſenſes; and in ſome caſes it is even conſiderable enough to produce actual fire. All that is requiſite for the production of

this laſt mentioned phenomenon, being a ſufficient degree of reſiſtance, a certain velocity of motion, and the preſence of air. On theſe principles we may eaſily explain the firing of a boat by the friction of a rope drawn with great ſwiftneſs againſt the edge of it, or the glowing of a ſmall piece of iron nimbly hammered on all ſides in quick ſucceſſion. But the fuſion, and even ſcorification of ſteel, by a ſingle percuſſion againſt a ſharp flint, would perhaps exceed our belief, did not theſe facts fall daily under our obſervation. When, however, we conſider that the bodies, from which the heat is generated, are extremely ſmall, (both the flint and the ſteel being ſtruck off from a comparatively large maſs) and conſequently that they preſent but a ſmall quantity of matter, through which the heat, now become active, can be diffuſed; and if to this we add the reflection, that the ſurrounding air, not being able, at leaſt in any conſiderable degree, to conduct the heat from the particle ſtruck off from the ſteel, ſerves rather to compreſs it and keep it in this ſubſtance, which, on the other hand, is known to be an excellent conductor of this fluid;

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all theſe circumſtances being duly weighed, we ſhall find reaſon to ſuppoſe the concentration of heat in the metallic corpuſcle is very conſiderable, and fully ſufficient to effect, by the aſſiſtance of the ambient air, a rapid combuſtion of the metal *.

Having juſt indicated to the intelligent reader thoſe circumſtances, in which the facts arranged under our ſecond diviſion, coincide with thoſe of the firſt, we are the leſs ſolicitous to ſhew the connexion between our firſt and third head: as the difference is ſo ſmall, that were it not that the air is neceſſarily concerned in the one caſe, and not in the other, we ſhould conclude them to be exactly the ſame. For, what is every decompoſition of phlogiſton by the air, but the actual commenſtruation of theſe two ſubſtances? And how are we to diſtinguiſh them from ordinary commenſtruations, but that in the former, heat is generated by the decompoſition of the bodies producing it; in the latter without

* Mr. Scheele's account, Sect. 79. *of his Treatiſe*, does not materially differ from that in the text, except that he ſuppoſes the heat to proceed only from the ſteel, in which it was before, as it were, incloſed.

any decompoſition at all.—Of both theſe modes of generating heat, we have a notable inſtance in the effects conſequent on the colliſion of a flint againſt a piece of ſteel. In the beginning of this proceſs we find heat produced without light, and without the decompoſition of either flint or ſteel; and afterwards, by the decompoſition of the ſteel, not only the heat is augmented, but light likewiſe is evolved, and diffuſed through the atmoſphere. The former part of the proceſs comes under the head of *commenſtruation*; the latter under that of *phlogiſtication of the air*. The latter can have place only in phlogiſtic, *i. e.* inflammable ſubſtances; the former in all ſubſtances whatſoever, whether one of them be inflammable, or both, or neither.

The reaſon, why in the caſe of ſimple commenſtruation, the commenſtruating bodies are not neceſſarily decompoſed, is, that the heat not making an eſſential part of theſe bodies, when by their mutual attraction it is expelled, they will attract each other as forcibly as before, nay more forcibly; and conſequently, their coheſion will be ſo far from being weakened, that it will rather be increaſed. Whereas

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in the caſe of moſt inflammable bodies, the heat being combined with the matter of light is fixed in them, and makes an eſſential part of their ſubſtance: now when this combination of heat and light (uſually termed phlogiſton) is attracted from them by the air, the remaining elements muſt neceſſarily be diſjoined, as previous to this action of the air, they did not attract each other more, than they attracted and were attracted by, the phlogiſton contained in the common maſs. Where, indeed, the phlogiſton is not ſtrictly combined, but merely mixed with the body, the ſeparation of this principle does not effect the total decompoſition of the ſubſtance, although ſome ſenſible change is always produced in it. The reader will find ſome examples of this kind in the dephlogiſtication of liver of ſulphur, and other phlogiſtic proceſſes enumerated in the following chapter.

As to what concerns the generation of heat by percuſſion, we have one obſervation to make by way of obviating an objection, which may ſeem to bear hard on the doctrine laid down in ſome of the preceding paragraphs. It may be aſked, when the matter of heat is extri-

cated from bodies by percuſſion, and is thus converted into ſenſible and active heat, how is it, that theſe bodies are never exhauſted, but ſeem to yield the fluid, which gives us the ſenſation of heat, *ad infinitum?* The anſwer is plain, that they muſt certainly receive a conſtant ſupply from the neighbouring bodies. But theſe muſt likewiſe be ſupplied in their turn, by other bodies in their vicinage. This matter then muſt be ſuppoſed to flow with the greateſt facility from any one ſubſtance repleniſhed with it, to any other contiguous ſubſtance, in which there is a deficiency of it; and though in certain circumſtances it be fixed and inelaſtic, muſt undoubtedly be poſſeſſed of great mobility and elaſticity. In all theſe particulars, it perfectly agrees with the electric fluid; therefore, as both analogy and the conſtant tenor of nature conſpire to eſtabliſh the foregoing hypotheſis, we ſhall not urge the reader any farther on the ſubject, but leave the reſt to his diſcernment.—There is a ſimilar difficulty attending the explication of our firſt diviſion, *viz.* commenſtruation; but as there are two very different, and indeed oppoſite opinions prevalent

prevalent among philoſophers on this point, we ſhall defer the conſideration of it to another opportunity.

CHAP. VI.

On thoſe Proceſſes in general, in which the Air is phlogiſticated.

THE theory of theſe proceſſes may be conveniently comprehended under two general canons:

CANON I.

Every combuſtible ſubſtance, which, being placed in contact with the air, loſes its combuſtibility either totally or in part, conſtantly generates, 1ſt, Heat, *and that in proportion to the quantity of action of the air upon it*; 2dly, *An uninflammable* permanently elaſtic *fluid*, miſcible *with water, and forming with it an acid, likewiſe converting lime into chalk*: 3dly, *An uninflammable* elaſtic permanent *fluid*, immiſcible *with water*.

All proceſſes, in which the above-mentioned circumſtances take place, are, by late writers,

(rather improperly) termed *phlogiſtic* proceſſes; for the impregnation of water, of ſpirits of nitre, oil of vitriol, calces of metals, and many other ſubſtances with phlogiſton, merit that title equally with the various operations by which the *air* is phlogiſticated. Theſe proceſſes, for the phlogiſtication of the air will be inveſtigated more particularly in the following chapters. At preſent we ſhall content ourſelves with giving a catalogue of the moſt conſpicuous of them, together with a ſhort explanatory comment on ſuch of them, as ſeem to require ſome elucidation.

1. Combuſtion, by means of air; 2. The diminution of nitrous gas, by means of air. 3. The dephlogiſtication of liver of ſulphur, by means of air: 4. Inſpiſſation of eſſential, and ſome other oils, by means of air. 5. Fermentation, by means of air. 6. Efferveſcence of iron with water, by means of air. 7. Efferveſcence of iron with water and ſulphur, by means of air. 8. Diſcoloration of metallic precipitates, by means of air. 9. Depuration of blood, by means of air? 10. The apyretous evaporation

poration of phoſphorus of urine, by means of air. 11. The paſſage of accumulated electric matter through the air.

(1.) Under the head of combuſtion is comprized (a) the combuſtion of inflammable air, (b) the kindling of phoſphorus, and of the different kinds of pyrophori (c), the calcination of metals, properly ſo called (d); the inflammation of oils by the nitrous acid (e); the detonation of nitre and of gunpowder, of pulvis fulminans, of fulminating gold, and of the fulminating mercurial precipitates. (4.) Theſe may in general be called drying oils. The heat here generated is not manifeſt to the ſenſes, becauſe as faſt as it is generated, it is neceſſarily abſorbed by the watery vapour exhaling from the oil. But if in reality no heat were extricated in this proceſs, the thermometer would indicate a greater degree of cold, than it ſhewed before its immerſion, which it does not. Therefore heat is produced. *Vide Scheele on Air and Fire*, Sect. 52. (7.) The heat is much greater with ſulphur than without, ſo that in this latter caſe it often riſes to inflammation. (8.) Two ounces of martial

vitriol

vitriol being diſſolved in water and a lixivium of cauſtic alkali added to it, the green precipitate reſulting from this mixture, was incloſed in an empty bottle, cloſely ſtopped, with its neck inverted in water, and capable of containing 24 ounces of that fluid: in the ſpace of a fortnight the precipitate had acquired the colour of crocus martis, and the bottle being opened under water, the air contained in it was found to be diminiſhed $\frac{6}{10}$ths. The ſame diminution happens to air to which iron diſſolved in vinegar has been expoſed, or a ſolution of copper in ſpirit of ſalt. *Scheele on Fire and Air*, Sect. 15. See likewiſe *Prieſtley*'s *Experiments and Obſervations*, page 288, *& ſeq.* (9.) It has not yet been remarked, that blood, either in or out of the body, produces heat on expoſure to air: but the reaſon may be eaſily gathered, from what has been advanced at the fourth proceſs. That the air is diminiſhed by this proceſs, we are certain, from Dr. Prieſtley's experiments on the ſubject; we have every reaſon therefore to conclude, that reſpiration, and in general every purification of blood by means of air, by which the colour of this animal fluid is from a reddiſh purple,

ple, approaching to blackneſs, changed to a florid red, is truly, what Dr. Prieſtley calls, a phlogiſtic proceſs. Perhaps the bleaching of wax and ſome other operations of a ſimilar nature, may be ranked among theſe proceſſes. The ſame may be ſaid of the fading of dyed ſilks and woollen, or other cloths, likewiſe of the change of colour obſervable in many other ſubſtances, when expoſed to the air.

Canon II.

The intenſity of the action of the air upon phlogiſtic ſubſtances, depends, 1. *On the degree of its purity or dephlogiſtication.* 2. *On that of its denſity or concentration.* 3. *On the quantity of air applied.* 4. *On the quantity or degree of heat applied* ab extra. 5. *On the mode of union of the phlogiſton of the body with its baſe.* 6. *On the quantity of action of any other matter extracting heat by percuſſion, or by commenſtruation with the phlogiſtic body.* 7. *In ſome ſubſtances, on the degree of fermentation excited.* 8. *On the extent of ſurface expoſed.* 9. *On the circumſtances influencing the communication of heat,* mentioned in the fourth chapter.

CHAP.

CHAP. VII.

On Inflammation and Combuſtion.

THE chief of the proceſſes enumerated in the foreging chapter, and that by which bodies are moſt completely changed and (if we may uſe the expreſſion) deſtroyed, is undoubtedly that of combuſtion. Of theſe we now propoſe to treat in a more ample manner: and as the inflammation is nothing more than the combuſtion of vapour, and as no body ſeems to burn without flame, we ſhall compriſe them both in the ſame chapter.

But nothing ſeems better adapted to illuſtrate the ſubject of chemical inflammation, than the flame of a candle; and as an excellent paper on this head, to the doctrine of which we in moſt points aſſent, has been lately publiſhed by Dr. George Fordyce, in Vol. 66, Part 2d, of the Philoſophical Tranſactions, we mean to make that paper (as far as it goes) the baſis of our illuſtration: departing from it however, and adding to it, as we may think proper.

When

When a candle is for the firſt time lighted, (which muſt be done by the application of actual flame) a degree of heat is given to the wick, ſufficient firſt to melt, and next to evaporate the tallow ſurrounding its lower ſurface; and juſt in this part the newly generated vapour is by admixture with the air, converted into a blue flame; which almoſt inſtantaneouſly encompaſſing the whole body of the vapour, communicates ſo much heat to it, as to make it emit a yellowiſh white light. The tallow now liquefied, as faſt as it boils away at the top of the wick, is, by the capillary attraction of the ſame wick, drawn up to ſupply the place of what is evaporated. The congeries of capillary tubes, which forms the wick, is black, becauſe it is converted into coal; a circumſtance common to it with all other vegetable and animal ſubſtances, when the oil which enters into their compoſition having been decompoſed by combuſtion, the more fixed part is by any means whatever covered and defended from the action of the air. In this caſe the burning ſubſtance owes its protection to the ſurrounding flame. For, when the wick, by the continual waſting of

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the tallow, becomes too long to ſupport itſelf in a perpendicular ſituation, the top of it projects out of the cone formed by the flame, and thus being expoſed to the action of the air, is ignited, loſes its blackneſs, and is preſently converted into aſhes.

That part of the flame, which comes into contact with the air, appears of blue colour; becauſe the red, yellow, and green rays uniting with the air, and probably with a portion of the fixed heat, compoſing the phlogiſton of the tallow, then all theſe uniting to form the elaſtic fluids, called fixed and phlogiſticated air, fluids well known to be generated in every ſpecies of combuſtion, the remaining blue and violet rays are neceſſarily emancipated together, with part of the heat, and reaſſume the rectilinear motion, always affected by the rays of light, when they are not attracted by other bodies.

The inner part of the flame differs from the outer, in being much denſer, and emitting a ſtrong yellowiſh white light, which has been called the light of ignition; while on the other hand, the blue has been ſuppoſed to conſtitute the light of inflammation. But every

flame being nothing more nor leſs than an ignited vapour, this diſtinction appears to be altogether groundleſs. At the ſame time it muſt be confeſſed, that theſe two parts of the flame, differing not only in colour, but almoſt in every other property, ought to be diſcriminated from each other by different epithets. The interior part then may be conſidered as (what it really is) an ignited body, and the light emitted by it may be called the light of ignition; while that proceeding from the exterior portion, may be denominated the light of combuſtion, for it is properly in this part of the flame, that the proceſs of combuſtion is carried on, and by that means a *tertium quid* produced; the ſucceeding phenomena being rather ſequels to, than making part of, this proceſs. Let us attend to theſe phenomena in their order.

When more vapour aſcends than can combine with the air in a given time, the remainder by the continued action of the blue flame ſurrounding it, ſuffers an accumulated degree of heat, and is ignited. This heat muſt be equal to that, by which the moſt denſe bodies, ſuch as metals, are made to emit a white light;

light; although on account of its greater rarity, the flame of a candle will not produce on thoſe bodies, to which it is applied, equal effects in a given time. However, it appears probable, that all bodies become luminous, (excluſively of the blue and feeble light of combuſtion) as ſoon as they have received a quantity of heat equal to that, which in metals cauſe the thermometer to riſe to between 600 and 700 degrees. The light iſſuing from *colourleſs* bodies, placed in theſe circumſtances, is at firſt red; becauſe the red rays having the ſtrongeſt attraction to the matter of heat, when the heat with which they were fixed in the body is emancipated, are conſequently detached along with it, and that before the reſt; but the heat *ab extra* being increaſed to more than 700° of Fahrenheit, the other rays are ſeparated in order, according to their different attractions for heat, and altogether compoſe a white light *.

* Mr. Elliot, in his "Eſſay on Combuſtion," has given an explanation of the origin of the different colours obſervable in the flames of combuſtion and ignition, in ſome reſpects ſimilar to the above, but in others widely different. He ſhould likewiſe have been noticed at

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It is true, that ſulphur, phoſphorus, and many other bodies, when they are made to burn ſlowly, exhibit only the blue light of combuſtion: and this is effected, by contriving, that no more ſhall be evaporated at any one time, than can be taken up by, and combined with the air. So if a degree of heat be given to phoſphorus not exceeding that of the common temperature of the atmoſphere; and if ſulphur be mixed with any ſubſtance, *e. g.* with chalk, or (if the heat applied be moderate) charcoal, as in the compoſition of gunpowder, which ſubſtances being leſs inflammable than the ſulphur, ſerve to divide its particles, ſo that it ſhall evaporate gradually; in theſe caſes the flame of both theſe combuſtible bodies, *viz.* the ſulphur and phoſphorus, will be entirely blue. But if the

page 46 as the only writer, who ſeemed to have made a proper diſtinction between combuſtion, ignition, and inflammation; but in fact, the far greater part of theſe ſheets were ready for the preſs, before the author had the curioſity to peruſe that gentleman's very ingenious treatiſe; a neglect, which proceeded entirely from the ſuppoſition of a perfect ſimilarity between his work and Dr. Crawford's.

ſulphur be ſet on fire, unmixed with other matters, and the heat of the phoſphorus be increaſed by friction, or otherwiſe, they will then throw out a white light, in the ſame manner as other denſer bodies, and the flame will be equally hot. Of this truth we have a remarkable inſtance in phoſphorus, which may be burned *ſlowly* in contact with the hands, or even the more tender parts of the ſkin, without ſcorching them, or exciting the leaſt pain: but when excited by friction, or by the application of external heat, it will burn the human fleſh, and other ſubſtances as readily as the flame of a candle, becauſe more vapour being then raiſed than the air can conſume, the remainder is ignited, and the heat of the whole flame is increaſed by the accumulation of heat on the ignited part.

Neither is it all to be wondered at, that the inner part of this vapour ſhould ſuffer a degree of heat equal to that, which in much denſer bodies, ſuffices to raiſe the thermometer above 700 degrees. For, although this vapour be very volatile, and would certainly fly off without ſuffering ignition, if the ſame degree of heat were in any other way applied to it; yet here being

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ſurrounded by the blue flame, (which being equally volatile, riſes with it) it cannot poſſibly eſcape the action of this flame, and as it has no means of parting with the heat thus communicated to it every inſtant, this fluid muſt neceſſarily accumulate to a great degree, till at length the vapour becomes ignited.

We muſt here beg leave to obſerve, after Dr. Fordyce and Sir Iſaac Newton *, that, although for the ſake of brevity and perſpicuity, we have ſuppoſed the ignited flame in general to be white, that of a tallow candle is in reality of a yellowiſh caſt, becauſe the empyreumatic oil, into which the tallow is converted during its evaporation, is of that colour. In like manner, the flame of zinc is of a brilliant white, and that of copper green: becauſe the calces of theſe metals are of thoſe colours. For a perfectly white body, not attracting any of the priſmatic colours, the rays of each colour will come from each point

* Newton, (*Optics*, *Query* 10*th*) obſerves, that "according to the nature of the ſmoke, the flame is of ſeveral colours, as that of ſulphur blue, that of copper opened with ſublimate green, that of tallow yellow, that of camphire white."

in its ſurface with juſt the ſame effect, as if they were reflected from it. But if the body have the power of reflecting rays of any particular colour, when expoſed to the light of the ſun, it will likewiſe have the power of emitting thoſe rays, during its inflammation, all the other rays being alike abſorbed in both caſes, and in the latter, almoſt at the very inſtant, in which they are emitted.

The phoſphorus of urine, together with the different kinds of pyrophori, are kindled with a very ſmall degree of heat; the former with a heat many degrees below, and the latter with one a very few degrees (if at all) above the common temperature of the atmoſphere. A far greater degree of heat is requiſite for the accenſion of ſulphur. Moſt other bodies, (not exceping æther and inflammable air) ſeem to require the preſence of light, as well as of heat, in order to their undergoing the operation of combuſtion; and accordingly actual fire, either as it exiſts in the ſolar rays collected into a focus, or in flame, or in other ignited bodies, is always applied to them for this purpoſe. But if we conſider, that neither ſpirits of wine, nor inflammable air,

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nor perhaps any other tranſparent ſubſtance can be ſet on fire by being placed in the focus of the moſt powerful burning lens or mirror, we muſt conclude, that the accenſion of the laſt mentioned claſs of bodies, depends merely on the degree of heat applied to them; and that the action of the flame, as well as that of other ignited bodies upon them, proceeds ſolely from its having acquired, and conſequently being able inſtantaneouſly to communicate a certain degree of heat, of which degree ignition is the criterion or ſign, both in the body firing and that to be fired.

It appears then, that there is only one circumſtance, in which conſiſts the great difference obſervable in bodies with regard to the facility or difficulty of their accenſion. This is the degree of heat applied. But if we would go ſtill farther, and inveſtigate the cauſe of this different diſpoſition in different bodies, when ſubjected to a determinate degree of heat, to part with their phlogiſton to the air in a ſtate entirely diſengaged and free from all other matter, we muſt firſt of all conſider, that the degree of purity in the air or attract-

ing matter being given, the force of attraction is given likewiſe; and that phlogiſton being neceſſarily the ſame in all bodies whatſoever, the air has equal power to attract it from one body as from another; ſuppoſing the degrees of heat applied, and the reſiſting forces in both bodies to be equal. But if the reſiſting forces be unequal, then the ſeparation of phlogiſton will take place in the inverſe proportion of their reſiſtances. Now the reſiſtance made by any body to the ſeparation of its phlogiſton, depends on the force of attraction between them. This may be either very ſmall, as in the caſe of diffuſion, of which we have an inſtance in liver of ſulphur; or it may be greater, as in the caſe of mixture, or it may be the greateſt poſſible, as in the caſe of combination. We have here then three different ſtates, in which phlogiſton exiſts in bodies, and in each of which it muſt reſiſt its ſeparation from the body in a different degree. This alone muſt make a great diverſity in the combuſtibility of bodies; and if to this we add the different ratio of fixity, which the heterogeneous component parts of

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moſt phlogiſtic ſubſtances bear to each other, as a very powerful cauſe of ſeparation, we ſhall perhaps be able to account for the extraordinary diverſity appearing in them, with reſpect to the degree of heat neceſſary for their combuſtion. Thus, while ſpirits of wine, æther, inflammable air, and many other highly phlogiſticated ſubſtances require (on account of their being wholly volatile) the contact of actual flame, in order to their accenſion, by which means alone they can be brought to receive a degree of heat ſufficient to ſeparate their phlogiſton in its pure and active ſtate, after being previouſly converted into vapour; the phoſphorus of urine and pyrophori, give out their phlogiſton to the air in the ſmalleſt degree of heat; partly for the reaſons given below, and partly, becauſe they contain nothing volatile in that temperature of the atmoſphere, but mere phlogiſton; while the remainder is as fixed as moſt ſubſtances, and that of phoſphorus in particular, more ſo than almoſt any other liquid ſubſtance in nature.

We muſt take care, however, not to confound the proceſs of combuſtion with that of

the ſimple phlogiſtication of the air *. It is true, that excepting the production of light, the

* Mr. Scheele, in his definition of fire, Sect. 75. has very properly diſtinguiſhed between theſe two proceſſes; but by inſiſting on the diminution of the ambient air, as a mark of the preſence of fire, he has excluded from the catalogue of igneous ſubſtances, not only the rays of the ſun, but the greater part of what are generally termed incombuſtible bodies (ſuch as earths, ſtones, and ſalts) when put into a ſtate of incandeſcence. But none of theſe laſt have ever yet been denied in this ſtate to conſtitute, or at leaſt to contain fire: and in refuſing this title to the ſolar beams, he has unwittingly quitted the party of chemical pyrologiſts (of which he is in other reſpects the great ornament and ſupport) for that of the mechanical philoſopher's, to whoſe doctrines the general tenor of his theory, as well as of his experiments, is diametrically oppoſite. Had he indeed aſſerted, that whenever fire is *generated*, the ſurrounding air is always diminiſhed, he would have advanced, what no one could controvert. But ſurely fire exiſts where it is not generated, and therefore in the ſolar rays, which are nothing more than collections of heated particles of light proceeding from the ſun. With more propriety has he expunged from the liſt of theſe ſubſtances the Bolognian phoſphorus, that of Balduin and the electric fluid; and that not for the reaſons he aſſigns, *viz.* becauſe they can exiſt in places void of air, and becauſe the air ſuffers no change from their preſence; for with reſpect to the firſt of theſe bodies, this latter aſſertion is not

tene,

the other circumſtances attending theſe two proceſſes are the ſame, or where they differ elſe, they differ only in degree. There is the ſame generation of fixed and phlogiſticated air in both. The volume of the air in both is diminiſhed. Heat too is generated in both, but in very different quantities; and theſe quantities, where the heat is not abſorbed, appear to bear an inverſe proportion to the time, in which the ſeparation of the phlogiſton is effected †. So likewiſe in every ſimple phlogiſton of the air, of which we have inſtances in the ſpontaneous decompoſition of the liver of ſulphur, and of iron filings moiſtened with water, or of iron filings, ſulphur and water; alſo in the ſpontaneous inſpiſſation of eſſential oils, linſeed-oil and varniſh; and laſtly, in the diminution of nitrous air; when theſe are ſeverally expoſed to the common air in ſuffici-

true, if we may credit thoſe accurate experimentaliſts, Signor Volta and the Abbé Fontana; but in fact, becauſe they communicate no heat to the ſurrounding bodies, except from ſecondary cauſes. The truth is, in ſhort, that wherever there is heat and light, fire cannot properly be ſaid to be abſent.

† *Vide* Scheele, Sect. 51, 52. & *alibi*.

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ent quantities, and with a ſufficiently large ſurface: in all theſe operations we know from the experiments of Dr. Prieſtley and Mr. Scheele, that heat is conſtantly produced. But theſe cannot be called ſlow combuſtions, any more than the putrefaction of veal and fiſh, or what ſeems analogous to this, the emiſſion of light from the glow-worm, cantharis, and other inſects; although by theſe proceſſes the bodies are decompoſed; becauſe in the latter heat, in the former light is wanting.

Again, we ſhould obſerve, that all thoſe ſubſtances, which have a power of phlogiſticating the air without producing light, ſeem to contain their phlogiſton in a ſtate of mere diffuſion; ſo that the attraction between this principle and its baſe being very much diminiſhed by the interpoſition of a third ſubſtance, the air has power ſufficient to attract it, and carry it off from its baſe; forming with it, as in the caſe of combuſtion, both fixed and phlogiſticated air. With this difference indeed, that as no part of the compound, known by the name of phlogiſton, or the inflammable principle, here eſcapes under the form of light, the air is rendered much more noxious,

that

that is, it is more perfectly phlogiſticated than in the proceſs juſt mentioned, and but a ſmall quantity of heat is extricated, or rendered ſenſible.

For it is farther to be remarked, that heat applied to any body, in order to the accenſion of that body, acts on it in no other way than by dilating it, and conſequently counteracting the attraction between its parts, by which means the attraction of the air is enabled to operate in its full force on the inflammable principle: ſo that, what is effected by heat in moſt bodies, is in the liver of ſulphur and in the other ſubſtances above-mentioned, brought about by the interpoſition of a third body, which acts upon them exactly in the ſame manner, as heat does upon bodies in general in the caſe of combuſtion; *viz.* by weakening the attraction between the phlogiſton and its baſe.

Now this third ſubſtance, which enters the compoſition of this claſs of bodies, exiſting in them in a fixed, and conſequently inelaſtic ſtate, ſerves merely to weaken the attracting power of the phlogiſton to its baſe, without giving the leaſt motion to the former, or farther

ther aſſiſting in the ſeparation of theſe ſubſtances. Here then the air, as faſt as it attracts the phlogiſton, has time to unite with it, ſo that no part of this ſubtle compound flies off, without forming at the time a ſtrict union with the air; for if it did, it would evidently be decompoſed, and be converted into ſenſible light and heat.

But where the intimate union of the inflammable principle with its baſe is counteracted by heat alone, this latter, being in conſtant motion, will neceſſarily impart motion to the phlogiſton of the body, to which it is applied; ſo that the phlogiſton will be ſeparated, much faſter than the air can take it up. Hence ariſe the great increaſe of heat, and the production of light obſervable in moſt ſubſtances, when heat is applied to them *ab extra*, in a ſufficient degree, under the circumſtance of expoſure to the common air of the atmoſphere.

It is perhaps unneceſſary to mention, that when expoſed to the action of air purer than that of the atmoſphere, or of what Dr. Prieſtley has denominated dephlogiſticated air, theſe ſame ſubſtances will take fire with a much

leſs

leſs degree of heat, and in much leſs time; and likewiſe, that the combuſtion will be conſiderably more rapid than ordinary. But it may not be ſuperfluous to obſerve, with reſpect to the pyrophori *, (under which denomination we likewiſe include the phoſphorus of urine) that, although from the caſe, with which their phlogiſton is ſeparated, they ſeem to partake of the nature of thoſe ſubſtances,

* The phoſphorus of urine, otherwiſe called Kunckel's, and frequently (though very unjuſtly) Boyle's phoſphorus, was known to the philoſophic world ſome time before Homberg diſcovered the firſt pyrophorus: and as the emiſſion of light is the moſt remarkable circumſtance attending its combuſtion, when the accenſion is ſpontaneous and unaſſiſted by friction or heat *ab extra*, it is highly probable, that the obſervation of this circumſtance induced philoſophers to give it the name it now bears; and afterwards, when a ſubſtance was found, which was as remarkable for the production of heat as of light, to beſtow on that ſubſtance the name of *pyrophorus*, a term ſuggeſting the idea of fire, as *phoſphorus* does that of light. But it is evident, that heat being generated by both theſe bodies, they both ought to be comprehended under the former denomination; and conſequently, that the term phoſphorus ſhould be confined to ſuch ſubſtances, as emit light without heat; a phenomenon of which (to omit others of inferior note) we have remarkable inſtances in the phoſphorus of Balduin and the Bononian ſtone.

which

which ſimply phlogiſticate the air; yet, as they do not effect this *, till they are kindled by it, they muſt be allowed to remain in the ordinary claſs of combuſtibles, from which they differ only in degree †. In fact, if we examine

* This is to be underſtood with ſome limitation. Mr. Scheele has ſhewn, that the inflammation of Kunckel's phoſphorus, when the ſurrounding atmoſphere is not warm enough, may be produced, by cutting the phoſphorus into ſmall pieces, and thus, by the phlogiſtication of the air, producing a degree of heat ſufficient for the purpoſe. Sect. 76. Note (*a*). At leaſt, ſuch ſeems to be the author's meaning; and this interpretation is confirmed by analagous obſervations and experiments. The Abbé Fontana to has made it appear, that the air is leſs phlogiſticated by this ſubſtance when in the act of combuſtion than otherwiſe. We likewiſe know, that many of the pyrophori are under the ſame predicament, and will not take fire, till they have firſt phlogiſticated the air, and thereby generated heat ſufficient for their inflammation. But as we are at the ſame time pretty well aſſured, that in ſuch caſes the pyrophori are either imperfect, or elſe placed in an atmoſphere much colder than uſual; the conſiderations above recited, do not ſeem to form any weighty objections to the doctrine laid down in the text.

† The phoſphorus of urine may be placed at the head of this claſs; next to this come the various pyrophori in theorder of their accenſion; after theſe ſulphur: from this

examine into the origin and compoſition of theſe moſt combuſtible of all ſubſtances, we ſhall find reaſon to ſuppoſe, that they derive their peculiar property of taking fire in the common temperature of the atmoſphere, as much from the circumſtance of their poſſeſſing a greater quantity of the inflammable principle, than the air can readily unite with; as from that of their poſſeſſing it in a very looſe ſtate, or, as we would rather wiſh to expreſs it, in a ſtate of diffuſion.

We cannot quit this ſubject, without holding up to the reader's notice the extraordinary coincidence obſervable between the ideas of the vulgar, with reſpect to fire, as they are diſplayed in the beginning of this treatiſe,

this ſubſtance to inflammable air, æther, and vinous ſpirits, there is a great interval; none of theſe being inflammable without the contact of an ignited body. But there is a ſtill more eſſential difference between phoſphorus and the ordinary pyrophori, which deſerves to be taken notice of in this place. This is, that the former, like all oily matters, does not burn till it be firſt liquefied, and afterwards converted into vapour, ſo that the body of it (or the unvolatilized part) does not ſhine in the leaſt; while the latter exhibiting little or no flame, are ignited in their proper ſubſtance.

and thoſe of philoſophers in general, as exhibited in the diſtinctions they have very naturally *, though ſomewhat unjuſtly made between the pyrophori and the ordinary phoſphorus. This coincidence, however, is not more remarkable, than the oppoſition, that appears between their *theory*, and what may be properly enough, in this reſpect, called their *practice*. The philoſophers then *think* with us, and the reſt of mankind, however diſſentient on other occaſions may be their *language*. If nevertheleſs, we could poſſibly harbour any doubts concerning the plain and ſimple doctrine delivered in the preceding pages of this work, theſe conſiderations are ſurely ſufficient entirely and inſtantly to efface them.

* We ſay naturally, conſidering the ſtate of phyſical knowledge, when theſe ſubſtances were firſt diſcovered: though in the preſent ſtate of ſcience, it appears to be a diſtinction without a difference.

CHAP. VIII.

On the Deflagration of NITRE.

HITHERTO we have treated only of combuſtion as excited by expoſure to the atmoſphere; but that produced by the nitrous acid is no leſs curious in its effects, although inferior to the former in utility and univerſality. We therefore proceed to treat of this likewiſe; eſpecially, as the phenomena, however they may ſeem to differ from thoſe of ordinary combuſtion, are all to be derived from the ſame principle, and conſequently, after the preceding elucidations, cannot require much explanation.

When a piece of charcoal or other inflammable matter is thrown into a crucible, which contains nitre in fuſion, and heated to a certain degree, the charcoal becomes ignited, and a very bright flame iſſues from it, with a loud blaſt, where it is in contact with the nitre. The ſame thing happens, when nitre is thrown upon ignited charcoal. This proceſs is called

 deflagration,

deflagration, and ſometimes *detonation*; although this latter epithet would be more properly beſtowed upon it, when the ingredients being reduced into very ſmall particles, a conſiderable quantity is by that means fired in very quick ſucceſſion, ſo as to produce the appearance of a ſingle exploſion. This is the caſe with gunpowder, eſpecially when it is confined on all ſides, for then the air generated by its accenſion has not time to eſcape, as faſt as it is extricated; but ruſhing out, as it were, at once, ſtrikes the external air with accumulated velocity. But as the ſulphur commonly uſed in the preparation of this fatal compoſition, is not abſolutely neceſſary to its conſtitution*; it is evident, that the only eſſential difference between the proceſs for the deflagration of nitre, as it is uſually performed, and that for the detonation of gunpowder, conſiſts in the greater or leſs comminution of the ingredients. What then accounts for the former, will likewiſe involve the explanation of the latter. But preciſely herein lies the difficulty. The deflagration of nitre,

* Count Saluces. *Melanges de Philoſophie & de Mathematique.*

to

to all appearance ſo ſimple an operation, has nevertheleſs foiled the beſt philoſophers in their attempts to explain it; and even ſince Dr. Prieſtley's important diſcoveries, the nature of it is yet far from being perfectly underſtood. We apprehend, however, that from the preſent ſtate of our knowledge with reſpect to this intricate ſubject, there may be collected data ſufficient to enable us to account for the principal phenomena, and eſpecially to correct the falſe notions given us by ſeveral authors concerning the inflammation of gunpowder.

To begin then with the more ſimple proceſs of deflagration.—Nitre, in contact with an ignited body not containing phlogiſton, is known to yield a great quantity of exceedingly pure air. This property, however, is by no means peculiar to nitre; ſince it is found more or leſs in all incombuſtible earthy matters, capable of uniting with the nitrous acid, and which contain it in a concentrated ſtate. Among theſe, metallic bodies hold a diſtinguiſhed place *. But without ignition this air

* Mr. Scheele, by rejecting the interpoſition of *fire* in theſe and ſimilar operations, and ſetting up *heat* as the

air is not produced.—Other bodies likewiſe, which do not contain the leaſt particle of the nitrous or any other acid, yield a conſiderable

grand agent in its ſtead, has involved himſelf and his ſubject in unſurmountable difficulties, and has particularly drawn upon himſelf the juſt cenſures of Mr. Kirwan, his Engliſh commentator; who argues, that on this ſuppoſition metallic calces in general, or at leaſt black manganeſe muſt be reduced by bare heat, which neither Mr. Scheele nor any one elſe will aſſert. But is Mr. Kirwan himſelf much happier in his explanation of this difficult theorem, when he ſays, that "the air being dephlogiſticated "attracts the elementary fire in the calces, which is neceſ-"ſary to its exiſtence, that is, to the exiſtence of the de-"phlogiſticated air." Does this air then, like the animal and vegetable kingdom, require a pabulum? Nothing ſurely can exceed this inſtance of attachment to ſyſtem, except, perhaps, the remarkable conduct of Mr. Scheele in perſiſting throughout his whole book, to deny the efficacy of light in the ſeparation of air from, and the conſequent reduction of metallic bodies; when, at the ſame time, his great love of truth obliges him, in every inſtance but one, to aſſure us, that the ſalt or metallic body, or at leaſt the bottom of the retort containing it was made red hot. In this one experiment indeed he affirms, that the nitrous acid was decompoſed *before* the retort was red hot. Exp. 3. Sect. 34. But this being a ſingle and ſingular inſtance, was probably a deception. How rare are ſuch inſtances of candour in ſyſtematic writers!

quantity

quantity of the pureſt air. The chief of theſe are calcined mercury and minium. But neither do theſe, nor the precipitates and calces of any metals that have been previouſly diſſolved in other acids, produce uncontaminated air without ignition.—From thoſe ſubſtances indeed, which have abſorbed air from the atmoſphere, this air may be again ſeparated by the intervention of acids, without much, or even any additional heat. Of this we have inſtances, among others, in the production of pure air from red lead, when moiſtened either with ſpirit of vitriol or of nitre. But from the latter mixture much air is produced by ignition, after the air abſorbed by the lead during its calcination has been ſeparated by a moderate heat. This laſt circumſtance, however, ſeems ſolely owing to the decompoſition of the nitrous acid by the red lead, a ſubſtance by which it is ſtrongly attracted: as when oil of vitriol is poured on the ſame ſubſtance, no ſuch decompoſition takes place, and that probably, becauſe the attraction between theſe two bodies is not ſufficient to overcome that exiſting between the conſtituent parts of the acid; for, when the

vitriolic acid is poured upon iron, and diſtilled, a great quantity of pure air is produced over and above what can poſſibly be ſuppoſed to have been attracted by the iron during the ſolution *.

Now, if with Mr. Lavoiſier, we ſuppoſe not only the nitrous, but likewiſe all other acids to contain atmoſpherical air, which is not merely contained in their interſtices, but enters into their conſtitution, and without which they are no longer acids, we ſhall not perhaps be at a loſs to account for the preceding phenomena. To this conſtituent part of acids, joined with the earth and water, long ſince demonſtrated by Stahl to enter their compoſition, let us add the principle of heat, and we ſhall have every thing eſſential to form the *general* idea of acids; the ſmall

* Dr. Prieſtley found, that as much air might be procured by heat alone from red lead, as when vitriolic acid was added; and, in order to obviate any objections that might be made to the proceſs for obtaining pure air from martial vitriol, ſuch as its having abſorbed air from the atmoſphere and the like, he made the diſtillation in the ſame veſſel in which he had mixed the ingredients, and proceeded to diſtillation immediately.

quantity

quantity of fixed light, which, more or leſs, is contained (as it were) accidentally in them, ſerving merely to diſtinguiſh them ſpecifically from each other.

It is further to be obſerved, that of all the mineral acids, the nitrous containing the moſt phlogiſton (for by this epithet is generally deſigned that kind of igneous compound, in which the matter of light predominates) is on that account the moſt liable to be decompoſed by the ſeparating, or (as it is otherwiſe called) expanſive power of heat acting upon it, while it is ſtrongly attracted by any other body. Where the nitrous acid is combined with an alkaline or earthy baſe, their mutual attraction ſeems ſufficiently ſtrong of itſelf for this purpoſe. But when it is united with a metallic baſe, by far the greater part muſt be previouſly ſeparated by diſtillation, evaporation, or by the means of ſome ſubſtance, to which it has a ſtill ſtronger attraction; in which caſe, the very minute quantity then remaining, will be as forcibly attracted, as if it were combined with a fixed alkali, and perhaps more ſo; for in conſequence of the like treatment with metals, even the vitriolic and ma-

rine acids may be converted into reſpirable air; which, however, has not as yet been extracted from them, when theſe acids are united with alkalies or abſorbent earths.

Upon theſe principles it does not ſeem difficult to explain the production of air from the different ſubſtances, which have been uſually employed for that purpoſe. Let us firſt, however, examine (as the more ſimple caſe) what is the proper effect of ignition upon thoſe calces which are made by the ſole action of the air; and which, in conſequence of this ignition, giving out air in great quantity, we are very ſure muſt have abſorbed it previouſly from the atmoſphere. In the calces of the imperfect metals, indeed the changes made by ignition do not ſo evidently appear; but in that of mercury, the only one of the more perfect or noble metals, which we can ſubject to this experiment, (gold, ſilver, and platina, being not eaſily calcined by air alone) in the reduction of this metal we have ocular proofs, that as ſoon as the fire enters the calx, that is, as ſoon as the calx is ignited, it recovers the phlogiſton it had loſt by calcination in the open air; and at that inſtant the air it had before

fore abſorbed, is expelled by the phlogiſton reaſſuming its proper place in the metal. Here we ſee, that the calx attracts, and fixes juſt as much phlogiſton or light, as is neceſſary for its metallization: and tho' the proceſs ſhould be continued, and conſequently the light and heat ſtill continue to penetrate the retort, yet neither the metal nor the air would ſuffer any farther change, the former having already attracted as much phlogiſton as it is able to retain, and the latter having no power of fixing either light or heat in its ſubſtance, unleſs they be preſented to it in a different form. When, indeed, they are preſented in a combined ſtate, as they exiſt in bodies, or in other words, in the form of phlogiſton, to an ignited calx, in contact with air, in that caſe the calx, whether it be of a perfect or imperfect metal, is immediately reduced, and the ſuperfluous phlogiſton is tranſmitted to the air, forming with it fixed and phlogiſticated air.

Let us now ſee, whether this reaſoning will apply to thoſe more compound caſes, in which the different acids are combined with metals; proceeding all the while on the hypotheſis, that air is a conſtituent part of all acids, and is more

more eaſily extricated from the nitrous acid than from any other. It is chiefly on this latter accordingly, that we ſhall inſiſt in the following elucidation. When the red precipitate (as it is called) of mercury, is ſubjected to the action of fire in a retort, as ſoon as the bottom of the retort begins to glow, pure air is ſeparated in great quantity: at the ſame time a cloud of red fumes is viſible in the neck of the retort, and at length in the receiver itſelf; in fine, the whole mercury is revivified. The ſame phenomena preſent themſelves in the revivification of the other noble metals from their calces, and calciform alkaline precipitates. Now during the ſolution of theſe metals in the nitrous acid, and ſubſequent diſtillation to dryneſs (by which operations likewiſe a kind of calx is formed) the greater part of the phlogiſton of the metal is ſeparated along with the metal, in the form of nitrous gas, and nitrous acid gas. The calx is conſequently left in the ſtate of a dephlogiſticated earth, at leaſt with reſpect to its effect on the nitrous acid; the remainder of which acid it now attracts with greater force, than it did the whole before the disjunction; partly, becauſe it has

loſt

loſt the phlogiſton, which ſerved to repel the aërial and aqueous parts of the acid, and partly, perhaps, becauſe its action is now exerted on a much ſmaller quantity of matter, and therefore more commenſurate to the ſmall degree of attractive power with which it is endued. But when the maſs is once ignited, the phlogiſton of the fire entering it, the attraction of the calx to the aërial part of the acid is again weakened; and this air, which had before taken the place of the phlogiſton, now yields it again to its priſtine poſſeſſor in the manner explained concerning atmoſpherical air, in the preceding paragraph.

Having thus inveſtigated (as far as the obſcure and intricate nature of the ſubject will permit us) the circumſtances, in which pure air is produced from various ſubſtances, it remains for us to ſhew, what becomes of this air, and how it is affected in its deflagration with inflammable ſubſtances, and particularly with charcoal. This, however, is a taſk of no great difficulty, ſince the phenomena themſelves, collated with the latter experiments of Dr. Prieſtley, plainly evince, that as ſoon as a particle of air is generated, or rather

ther detached from the nitre by the action of the ignited matter, this particle, while yet in a ſtate of condenſation, immediately, and in the moſt rapid manner, unites with as much of the phlogiſton of the ignited body, as is ſufficient to ſaturate it, and is thereby converted into fixed and phlogiſticated air. A part of the phlogiſton being thus carried off by combuſtion, in the form of a blue flame, the diſcharge of light proceeds now from the phlogiſtic ſubſtance itſelf; whereas before (ſuppoſing the operation to be performed *in vacuo*) it was only from the fuel, on which the veſſel containing the ingredients was placed. Now, whatever ſubſtance is uſed in the deflagration, the light is ſeparated from it in great quantity, becauſe the combuſtion is extremely rapid; for the air being in a ſtate of great concentration, decompoſes the phlogiſton of the body ſubjected to its action, and conſequently extricates the heat of it in a quantity proportioned to the degree of its own concentration. This heat continually accumulating, at length ſeparates all the rays in a rapid, and as it were, in a tumultuous manner, by giving motion to the heat combined with them, in the form

of

of phlogiſton; and conſequently, inſtead of a red heat, which is the degree of heat generally excited in charcoal, a brilliant white heat is produced. In this likewiſe the blue flame of combuſtion muſt neceſſarily be very copious, although, on account of the extreme ſplendour of the light of ignition, it is not generally noticed; for fixed air is produced here in great quantity, when charcoal is uſed for the experiment; while, on the other hand, when metals are uſed, the produce of this acid is very inconſiderable. And this difference does not ſeem to proceed from the circumſtance of charcoal's containing much fixed air in its ſubſtance, while metals have none at all, but rather from the different degrees of facility with which theſe two bodies are burned; the inflammable principle of the former, for the reaſons given above, mixing in greater quantity, and more perfectly with the air, ſo as to afford more of the light of combuſtion than the latter. For it may be inferred from what has already been ſaid, that the produce of fixed air is always proportionate to the quantity of phlogiſton combined with the air in combuſtion; and that this produce

is

is greateſt, where there is no light detached, as in the ſimple phlogiſtications of the air, which (perhaps for this very reaſon) have been by ſome improperly termed ſlow combuſtions; that it is leſs (although ſtill conſiderable) where the flame is entirely blue, as in the caſe of ſulphur thrown upon iron heated below the ſhining point, and of other ſlow combuſtions, properly ſo called, ſtill leſs in ordinary combuſtions; and leaſt of all in ſuch as are rapid, where the heat excited is ſo great, as to cauſe a ſeparation of all the rays promiſcuouſly, and thus to produce a white heat in ſubſtances, which, in the ordinary mode of accenſion, burn with a red heat only. Thus, charcoal does not require a white heat, in order to part with its phlogiſton to air; but when this degree of heat is applied, it burns faſter than ordinary, and conſequently leſs fixed air than uſual is generated. On the other hand, metals cannot be accended but in a white heat. The quantity of phlogiſton therefore combined with the air in the combuſtion of metals, is not neceſſarily very great, and in that caſe the quantity of fixed air generated will be ſmall in proportion to that produced by charcoal;

coal; the greater part of the inflammable principle (of which, however, compared with charcoal, theſe bodies contain but a ſmall portion) being detached from them in the form of white light.

It appears then, that the greater diſpoſition any body has to part with its inflammable principle to the air, the greater power it has to fix that air; or, in other words, the greater the quantity of blue light, ſeparated from any particular body in the act of combuſtion, the greater is the produce of fixed and phlogiſticated air; and, *vice verſa*, the greater the intenſity of the light of ignition in that body, the leſs is the produce of fixed and phlogiſticated air. Having taken this into conſideration, we ſhall no longer be ſurprized at the wide difference obſervable between nitre alkalized by charcoal, and the ſame alkalized by metals: the former, after the operation, ſubſiſting in a mild, and the latter, in almoſt a cauſtic ſtate. We ſay, almoſt cauſtic, for it does not appear that it is ever abſolutely ſo, except, perhaps, the fire has been continued long enough to expel all the fixed air, which the alkali had previouſly abſorbed. Neither

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ſhould it be matter of wonder to us, that the elaſtic fluid caught in the receiver is merely phlogiſticated air; ſince the nitrous acid being in this proceſs completely decompoſed, and converted partly into pure air, and partly into light and heat; the fixed air likewiſe being all abſorbed by the alkali, nothing can poſſibly come over into the receiver, but the pure air now phlogiſticated in the courſe of the operation.

CHAP. IX.

On the Exploſion of GUNPOWDER.

WE ſhall now put an end to this ſubject, by a more circumſtantial enquiry into what paſſes in the exploſion of gunpowder. Dr. Ingenhouſz has lately given us a new theory of this proceſs *; but, for want of paying proper attention to the lights afforded us by Dr. Prieſtley's lateſt experiments, he ſeems to have receded farther from the truth than his predeceſſors, who were entirely ignorant of

* Philoſ. Tranſact. Vol. lxix. part 2d.

them.

them. Theſe finding, that an elaſtic fluid was diſengaged in great quantities from the ingredients when ſeparate, juſtly concluded, that the ſudden extrication of this fluid in a relatively ſmall ſpace, was the cauſe of this phenomenon. But of the nature of the fluid itſelf, they had neceſſarily very imperfect ideas. The important diſcoveries of Dr. Prieſtley, relative to the decompoſition of the nitrous acid, and the production of dephlogiſticated air, naturally led Dr. Ingenhouſz to the true theory of this aſtoniſhing appearance; but not being able to account for the brilliancy of the flame generated in the exploſion, he has had recourſe to the formation of a gratuitous inflammable air; which, however, does not appear by any means to anſwer his purpoſe. For (ſuppoſing for a moment the exiſtence of this inflammable air in charcoal) do not the difficulties he labours under in accounting for the different degrees of velocity attending the accenſion and exploſion of gunpowder, æthereal vapour, and inflammable air, ſufficiently convince us, that his theory muſt be in ſome points defective? But the fact is, that the ſuppoſition of the exiſtence of inflammable air,

ready formed in charcoal, is as void of foundation, as it is needleſs. For he muſt either allow that fixed air does exiſt ready formed in bodies, or that it does not. If the former; we know that the quantity of fixed air, produced by the burning of charcoal, is very great, when compared with that of inflammable air, extricated from the ſame ſubſtance. The inflammable air then is ſo far from being capable of burning, that it muſt rather extinguiſh flame by means of the fixed air mixing with it. But if we ſuppoſe (as Dr. Ingenhouſz in fact does, in a late ingenious treatiſe) that fixed air is generated by the combuſtion of charcoal, and not merely educed from that ſubſtance; then we ought certainly to allow, that the ſame holds good with reſpect to inflammable air produced at the ſame time from the ſame body, and under the very ſame circumſtances. This new doctrine therefore of inflammable air, exiſting ready formed in bodies, is abſolutely void of foundation; and were it true, the hypotheſis is totally unneceſſary, becauſe the phenomena are better accounted for by the infinitely more

more ſimple, and uncontrovertible doctrine of phlogiſton.

The principal reaſons, which hinder this gentleman from acceding to the generally received theory, appear to be, 1ſt, That he does not underſtand from this hypotheſis, why one ſpark of fire thrown into a heap of gunpowder ſhould, almoſt in one inſtant, ſpread the conflagration through the whole maſs; and 2dly, That he does not clearly comprehend, why this exploſion is accompanied by a moſt brilliant flame. The manner in which the extrication is carried on, has been fully explained above, and as to the time, in which it is performed, it is far from being inſtantaneous. When, indeed, the powder is forcibly confined in a very ſmall ſpace, as it is in firearms, the air extricated from a few grains, not finding a vent, and conſequently being kept in contact with the remaining powder, becomes heated, and therefore acts upon it, to the greateſt advantage. It is no wonder then, that, after the decompoſition of a very few grains (which decompoſition, it ſhould be obſerved, generates an additional degree of heat) the remaining powder (or rather a quantity

of it ſufficient to produce the effect) ſhould be decompoſed ſo ſuddenly, as to overcome the obſtacle oppoſed to the egreſs of the newly generated elaſtic fluid. As to the ſplendour of the flame produced by the exploſion, it is evidently occaſioned by the great heat excited by the ſuddenneſs and celerity of the combuſtion, which again are very much promoted, as well by the great purity and condenſed ſtate of the extricated air, as by the minuteneſs of the coaly matter, which is the chief inflammable ingredient. From theſe cauſes the charcoal, inſtead of yielding a feeble blue flame, as it does in the uſual method of accenſion, in this inſtance gives out a vivid white light.

It will not perhaps be impertinent in this place, to attempt accounting for a very remarkable phenomenon attending the blowing up of magazines and other buildings, in which gunpowder is kept. The phenomenon we ſhall ſpeak of, is, that the windows of ſuch buildings are conſtantly obſerved to lean inwards after the exploſion, as if they had been broken by a force acting upon them from without. It ſhould ſeem, on a ſlight view of the matter,

matter, that the windows would be the firſt parts of the edifice to ſuffer from the expanſive force of the confined air. But we are to conſider, on the other hand, that the air extricated from the powder being not only heated, but likewiſe, in a conſiderable degree phlogiſticated, is, on both theſe accounts, rendered much lighter than it was before; and, therefore, making its way out at the roof, and driving before it the atmoſpheric air already exiſting in the building, without much increaſing the preſſure of this latter on the ſides, the whole quantity of air remaining, continues to be lighter than the external air, till ſuch time as the ſuperior weight and elaſticity of this latter ſhall have overcome the impetus of the former. But, in the mean time, there is an opportunity for that part of the atmoſphere, which is contiguous to the ſides of the building to preſs inwards, in order to reſtore the equilibrium; the windows and ſlighter parts of the edifice are conſequently broken *ab extra*. There is, beſides, another circumſtance, which may ſomewhat contribute towards diminiſhing the preſſure of the internal air. This is the fixation of part of the air by

combuſtion, which fixation is as ſudden as the combuſtion itſelf, and follows it ſo quick, as, in point of time, not to be ſenſibly diſtinct from it.

Having thus treated largely on the detonation of gunpowder, we ſhall now beſtow a few conſiderations on ſome other proceſſes, analagous to this in cauſe, as well as in effect.

CHAP. X.

On the Exploſion of PULVIS FULMINANS.

THE very loud report made by the accenſion of a mixture, conſiſting of three parts of nitre, two of ſalt of tartar, and one of ſulphur, and that without being confined otherwiſe than by the ſurrounding air, has long been an object of attention to philoſophers, and of aſtoniſhment to the reſt of mankind. But no one ſeems hitherto to have given an adequate ſolution of this wonderful phenomenon. Before the diſcoveries of the Engliſh philoſophers on the ſubject of the elaſtic fluids, the reaſons given for the exploſion

of this compoſition, as well as for that of gunpowder, were too ridiculous to deſerve being mentioned here. But, after Boyle and Hales had found, that an elaſtic fluid was ſeparable from the ingredients, as well of this ſubſtance as of gunpowder, the ſuperior ſagacity of Sir Iſaac Newton, could not long be utterly at a loſs for the reaſon of both theſe exploſions. He has accordingly told us in general terms, that the phenomena of both proceed from a very quick and ſudden extrication of an elaſtic fluid, which in pulvis fulminans, however, is much more rapid than in gunpowder. With reſpect to the particular circumſtances, that concur to form the proximate cauſe of theſe appearances, his exquiſite judgment enjoined him to be ſilent; as the deficiency of experimental knowledge on this topic afforded room for nothing, but wild conjectures.

Since his time, indeed, ſeveral different theories of the action of this fulminating powder have been offered to the public. Some would endeavour to perſuade us, that the phlogiſton of the ſulphur is not ſo eaſily ſeparated, when the ſulphur is pure, as when an alkali is com-

bined with it. But this is true only to a certain point, and with reſpect to that indefinitely ſmall quantity of phlogiſton, which every inſtant is ſeparated ſpontaneouſly from liver of ſulphur in the open air, and without combuſtion. For, when theſe two ſubſtances are ſubmitted to the action of fire, till they are kindled by it, it will be found, that ſulphur alone kindles with much leſs heat, than when combined with an alkali *. Another opinion is, that the liver of ſulphur, being capable of entering into fuſion a long time before it becomes inflamed, by its viſcidity, when in a ſtate of fuſion, keeps the newly generated air from being totally ſeparated, which therefore forms bubbles at the top, till at length the maſs, and conſequently the force, of this elaſtic fluid becomes ſo great, as to overcome the reſiſtance made by the ſuperincumbent mixture, with a rapid and loud exploſion.

This theory has been adopted by Dr. Ingenhouſz, with little more alteration than the addition of an inflammable air, generated from the ſulphur. But, not to repeat what we have

* Count Saluce, Miſcell. Taurinenſia, Vol. i. p. 145.

already

already ſaid on the ſubject, when treating of gunpowder, it is abſurd to imagine, that the very ſmall force of coheſion exiſting between the particles of liver of ſulphur, is capable of confining (though for a ſhort time) a quantity of air, which, if we do not mean to trifle, we muſt ſuppoſe, at leaſt equal to the liver of ſulphur itſelf in bulk; neither is it poſſible to conceive the reaſon, why the remainder of the air (which remainder is indeed little leſs than the whole of it, and certainly occupies a ſpace many times greater than the whole mixture) ſhould be extricated ſo inſtantaneouſly, as it neceſſarily muſt be, to enable us to account for the phenomena; except we adopt the reaſoning of Dr. Ingenhouſz, who, with the greateſt probability aſſerts, that this circumſtance is occaſioned by the *accenſion* of the ſulphur. This, we think, no one will be diſpoſed to deny; but then the preceding ſuppoſitions of the confinement of the elaſtic fluid by the viſcidity of the mixture, and indeed the whole ratiocination (whether agreeable to the laws of mechanics or not, we do not now examine) are totally unneceſſary. The ſimple fact is, that the mixture being placed upon the fire,

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is firſt fuſed, at length boils, and when it has ſuffered a certain degree of heat, and not before, generates in the moſt rapid manner, a great quantity of an elaſtic fluid, or in other words, explodes with great violence. Neither is there any reaſon to imagine, that the generation of bubbles, which takes place long before the exploſion, and before the heat riſes to any great degree, proceeds from any thing more than the converſion of the moſt heated part of the liquefied maſs into mere vapour, as happens in the ebullition of water and all other liquids. For what will account for the extrication of one particle of elaſtic fluid, will account for the extrication of the whole; and as nitre, in certain circumſtances, yields a great quantity of permanently elaſtic fluid, we need not have recourſe to any thing more than the decompoſition of this ſalt for the explication of the phenomenon in queſtion. But we have endeavoured to ſhew before, that without ignition the nitre cannot be decompoſed; and accordingly, a blue flame is always the immediate fore-runner of this terrible exploſion.

On theſe principles, the explanation of the whole proceſs becomes very eaſy. The principal circumſtance, which diſtinguiſhes the pulvis fulminans from gunpowder, is this, that the particles of the latter explode evidently in ſucceſſion, and therefore it muſt neceſſarily be confined in a ſmall ſpace, in order to produce a ſmart concuſſion of the external air: while the former, to all appearance, is fired all at once, and with ſuch an inconceivable rapidity, that although it be not confined by any thing more than the external air, this has not time to retire from its impulſe, without receiving a violent concuſſion, and conſequently producing a very loud report. The difference then of the effects is only that of more and leſs. The cauſes, conſequently, can differ only in degree. Beſides, a proper attention to another particular obſervable in the firing of the fulminating powder, *viz.* that it requires to be ſlowly heated in order to produce its full effect, will ſerve to throw ſtill more light on this ſubject. For we are very certain, that in the caſe of gunpowder, that part only, which is in contact with a heated body, is firſt fired, and the reſt merely in ſucceſſion; likewiſe,

wiſe, that if this compoſition be heated ſlowly, the ſulphur will be ſeparated from it by ſublimation, and the powder will afterwards with great difficulty explode. It appears then, that the chief uſe of the alkaline ſalt in the pulvis fulminans, is to hinder the ſulphur from being diſſipated, until the whole mixture have acquired the degree of heat requiſite for the accenſion of the ſulphur. Then, as this ingredient is intimately mixed with the reſt of the maſs, juſt after the blue light proceeding from the *inflammation* of the ſulphur is perceived, the remainder of this inflammable ingredient is ignited, and with it the nitre, previouſly divided into the moſt minute particles, and equally diſtributed through its ſubſtance: the conſequence of all which is, an inſtantaneous, and therefore moſt violent exploſion of the whole mixture.

Now the compoſition of gunpowder is by no means calculated to favour ſuch a ſudden inflammation; 1ſt, Becauſe the charcoal, being neither ſoluble nor fuſible, cannot be reduced by the moſt accurate trituration to that ſtate of comminution and tenuity, in which the different ingredients of the pulvis fulmi-

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nans are known to exiſt: 2dly, Becauſe the ſulphur contained in gunpowder, not being fixed by an alkali, is either immediately volatilized by a gentle heat, and thus ſeparated from the other ingredients, without having anſwered the propoſed end, *viz.* that of communicating to them the additional heat ariſing from its inflammation; or elſe it is indeed inflamed by means of a more ſudden and violent heat; but on account of the nitre and charcoal not having been previouſly heated, it burns only in the place where it has been in contact with the heating body, and conſequently ſets fire to theſe other ingredients in a gradual and (comparatively ſpeaking) a ſlow manner.

We may now perceive the reaſon of the difficulties which Dr. Ingenhouſz found in accounting for the different circumſtances attending the inflammation of gunpowder, inflammable air, and the inflammable ætherial vapour. The two laſt having no ſolid particles, are conſequently fired (as it were) inſtantaneouſly, eſpecially as each particle of the inflammable elaſtic fluid is in contact with a particle of common or dephlogiſticated air.

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The exploſion, however, is leſs in theſe than in gunpowder, becauſe the expanſion is much leſs. But the exploſion of the pulvis fulminans much exceeds all thoſe hitherto mentioned, becauſe it unites the advantages of them all, *viz.* expanſibility and quickneſs of combuſtion; although, perhaps, it may not poſſeſs both theſe qualities in a ſuperior degree. The ſame reaſon may be given for the ſuperiority of the ætherial vapour over the inflammable air from metals, in point of force of exploſion, for the vapour of æther containing more phlogiſton, and that in a more denſe ſtate than the ordinary inflammable air, is more expanded by combuſtion with dephlogiſticated air than the latter; although, when common air is applied to this vapour, the mixture does not ſo eaſily take fire, and the exploſion is leſs powerful, becauſe the atmoſpherical air has not attractive force ſufficient eaſily to overcome that of the ætherial fluid to its inflammable principle, notwithſtanding that it may be perfectly equal to the moſt rapid evolution of this principle, as it is contained in common inflammable air.

With reſpect to the uſe of ſulphur in the compoſition of gunpowder, we ſhall juſt obſerve, that both Dr. Ingenhouſz, and Count Saluce himſelf, ſeem to have been miſtaken in the inferences they have drawn from the experiments of the latter gentleman. In direct oppoſition to the accurate experiments related in the Count's third memoir (*Melanges de Philoſophie, &c. Sect.* 15. & 19. *Exp.* vi, vii, viii.) they aſſert, that gunpowder made without ſulphur is more eaſily inflamed, and therefore explodes more ſuddenly and with greater force, than that into the compoſition of which this mineral enters. Count Saluce appears to found his opinion on ſome experiments which he had formerly made and communicated to the public, in a preceding memoir (*Miſcellanea Taurinenſia, Vol.* i. *Memoire* 2*de. Sect.* 43. & 64.) But the concluſions which he draws from the circumſtance of ſulphur making a ſlighter and leſs ſudden exploſion with nitre, than charcoal does, are very unſatisfactory, and indeed unwarrantable.

For in the firſt place, it is not true, that the latter mixture is more eaſily inflamed than the former; ſince the ſulphur detonated (when expoſed

poſed to an equable heat) at 25 vibrations of a pendulum, while the charcoal did not begin to deflagrate, till the ſame pendulum had vibrated 37 times. (*Memoire 3eme. Sect.* 19. *Exp.* iv. & vi.) That charcoal explodes more briſkly, and with greater force than ſulphur, will not be denied; but this circumſtance ſeems to be leſs owing to thoſe cauſes, which this author has mentioned, *Mem. 2de. Sect.* 43, 44. *& alibi*, than to the ſuperior fixity of charcoal, when compared with that of ſulphur, by which property it is better adapted to the purpoſe of ignition. A fortiori then, the concluſion muſt fail with reſpect to gunpowder; which, containing both the ingredients in queſtion, muſt neceſſarily act with the force of both; and accordingly we are told (Sect. 19. Exp. x.) that it began to detonate, when the pendulum had made only 16 vibrations, while the pulvis fulminans did not explode till the 32d. But this latter ſubſtance contains as much ſulphur in its compoſition, as gunpowder does, nay, more in proportion to the other ingredients; yet we find, when once it has acquired ſufficient heat, it is much quicker in exploding, and conſequently, though it does

not

not contain an atom of charcoal, explodes with much greater force.

In the ſecond place, although it be true, that the uſe of ſulphur in the compoſition of gunpowder, is to ſet fire to the maſs, with a leſs degree of heat, this does not ſeem to be the ſole uſe of this ingredient. Indeed, it is not eaſy to underſtand, how the admixture of any ingredient in a compoſition, ſhall occaſion that compoſition to take fire with a leſs degree of heat, than it would otherwiſe, while the omiſſion of this ſame ingredient, ſhall cauſe it to be more eaſily inflamed. But leaving the authors of theſe ſtrange ſuppoſitions to account for their congruity, we ſhall beg leave to obſerve, that there is another uſe of ſulphur, of perhaps equal importance with that juſt mentioned, and which ariſes from its great fuſibility. For, in conſequence of this property of being rendered fluid by a very ſlight degree of heat, as ſoon as thoſe grains of the gunpowder, which are in contact with the heating body, are ſet on fire, the ſulphur of the neighbouring grains is melted, and thus forms a communication between the grains, which did not exiſt before; ſo that the whole

maſs is fired much more ſuddenly, and therefore explodes more forcibly than it would, were the ſulphur omitted.

From this view of the uſe of ſulphur in the compoſition of gunpowder, we are enabled ſtill better than before, to anſwer the firſt query propoſed by Dr. Ingenhouſz, *viz.* why a ſpark of fire ſhould almoſt inſtantaneouſly kindle a large heap of this deſtructive mixture. Farther, we may hence perceive, that the great uſe of interſtices between the grains, does not ariſe from the ſpace which they afford for the projection of the ignited particles in every direction among the reſt, as this gentleman affirms: but firſt, from their containing the atmoſpherical air in greater quantity than when the interſtices are ſmall, as they are in a ſquib; for we know from the beautiful experiments of Mr. Lavoiſier, that the nitre in gunpowder cannot detonate, except that detonation be begun by a ſmall quantity of air, and therefore we may infer, that neither can the detonation proceed ſo well without the preſence of this fluid. 2dly, The great uſe of interſtices muſt proceed from their allowing room for the melting ſulphur to flow between

the grains. By this means the ſulphur expoſing a large ſurface to the air, and perhaps entangling that, which already exiſts in the interſtices, is eaſily ſet on fire, and thus ſpeedily fires the particles of charcoal, which it every where encompaſſes.

CHAP. XI.

On the Exploſion of Aurum Fulminans, *and of the fulminating mercurial Precipitates of* M. Bayen.

BESIDES the exploſive mixtures lately mentioned, there are many others worthy of notice; particularly the fulminating preparations of mercury lately diſcovered by M. Bayen, and that ſtill more ſingular ſubſtance, known by the name of aurum fulminans. With reſpect to the former, it is not neceſſary to enter into a circumſtantial detail, as the reader will eaſily perceive, from what has been ſaid before on the ſubject of metallic calces, that the reductions made by M. Bayen, which are attended with violent exploſions, differ from thoſe brought about in the uſual

method without exploſion, only by the rapidity and ſuddenneſs with which they are performed. We ſhall therefore content ourſelves with obſerving, that the ſulphur here operates in the manner we have before explained, when treating of gunpowder and pulvis fulminans, *viz.* by rendering the inflammation, and conſequently the exploſion and reduction almoſt inſtantaneous; an event, which does not take place, when the reduction is attempted either alone, or by the aſſiſtance of charcoal. And, in order that this operation may be effected as expeditiouſly and ſuddenly as poſſible, all the ſuperfluous acid is previouſly expelled by the addition of an alkaline ſubſtance; and if this have not force of attraction ſufficient for the purpoſe, the calx is afterwards deprived of the remainder of the adhering acid by heat.

The peculiar phenomena attending the reduction of fulminating gold, are to be explained in a ſomewhat different manner, although in a great meaſure on the ſame principle. All other calces are irreducible without previous ignition; neither do M. Bayen's precipitates fulminate, till the ſulphur with

which

which they are mixed becomes ignited; while even the ſmall degree of heat produced by moderate triture, is ſufficient for the reduction of this calciform precipitate: the reaſon will probably be found in the great attraction, which the earth of gold has for phlogiſton, joined to the intimate mixture of the volatile alkali (affording this phlogiſton) with and throughout the ſubſtance of the calx of gold.

Neither in fact is this calx, any more than others, reducible without ignition; but it differs from all the reſt of the metallic calces and precipitates, chiefly in this reſpect, that the heat uſed in its reduction is ſo ſmall, as to make us imagine rather, that the ignition happens in conſequence of the reduction, than the reduction in conſequence of the ignition. That the latter, however, is the caſe, not only the analogy of other calces of the noble metals would perſuade us; but ſtill more our knowledge of the inflammability of the dry volatile alkali, joined to the conſideration, that the pureſt air in the moſt condenſed ſtate is preſent and contained in the acid, from which the earth of gold has been precipitated, and conſequently in the earth of gold itſelf;

ſince all precipitates partake of the menſtrua by which they were firſt diſſolved.

It appears then, that this calx is ignited in conſequence of the inflammation of the vola tile alkali; which inflammation is cauſed partly by the attraction of the calx to the acid, and partly by that of the acid to the alkali. For the mutual attraction of the two former bodies paves the way (as in other combinations of this kind) to the decompoſition of the acid by heat, and its converſion into dephlogiſticated air; while the attraction between the acid and the alkali not only favours this decompoſition, but likewiſe by occaſioning the moſt intimate union of the air exiſting in the acid with the phlogiſton of the alkali, is the cauſe of this latter being inflamed by a very ſlight degree of heat.

That the elaſtic fluid generated in this experiment is phlogiſticated air, we have not only reaſon to ſuſpect from analogy, but we have likewiſe the moſt poſitive proofs of it from Mr. Scheele's experiment. (Sect. 82.) It is not a little ſurpriſing therefore, that ſo good a philoſopher and ready an experimentaliſt as Dr. Prieſtley,

Prieſtley *, ſhould call in doubt a fact, which carries with it ſo reſpectable a teſtimony as that of Mr. Scheele, eſpecially when it does not appear, that he has been at the pains of making any experiment to ſet in oppoſition to this fact. Mr. Scheele himſelf ſeems to have given weight to the contrary opinion, by admitting of the deſtruction of the volatile alkali in this, as well as in other inſtances. But this ſubſtance is in reality indeſtructible, as from this very experiment of Mr. Scheele, is evident; and with reſpect to the various preparations to which he refers in favour of his poſition, *viz.* nitrous ammoniac, corroſive ſublimate precipitated by volatile alkali, and crocus martis mixed with common ammoniac; theſe indeed, when properly treated by fire, afford irrefragable proofs of the generation of phlogiſticated air from acids, by the addition of phlogiſtic matter; a truth, we have been at much pains to inculcate in the preceding chapters; but can by no means be conſidered as demonſtrative, either of the de-

* In a letter to Mr. Kirwan, printed at the end of Forſter's tranſlation of Scheele.

ſtruction of the volatile alkali, or of its converſion into phlogiſticated air.

From the experiment above cited we find, that the volatile alkali, which enters the compoſition of fulminating gold, is ſublimed the moment the calx is reduced: an advantage we ſhould in vain expect from either of the fixed alkalies, which for want of this volatile property (even though they were phlogiſticated in the higheſt degree) would ever form an obſtacle to the reduction of the precipitate. Add to this, the ſmall degree of attraction manifeſted by the fixed alkalies towards gold or its calces; and we ſhall be convinced, that the volatile alkali is peculiarly fitted for the purpoſe of forming with gold a mixture exploding with a leſs degree of heat than any other compoſition hitherto diſcovered; and that the peculiar properties of this wonderful ſubſtance, depend chiefly on the decompoſition of a vitriolic, nitrous, or muriatic ammoniac diffuſed through, and intimately combined with the earth of gold; which earth, by its great denſity, is enabled to accumulate heat ſufficient to ignite in the moſt rapid manner the ammoniacal ſalt, and by its ſtrong attraction

traction to phlogiſton to be at the ſame inſtant itſelf reduced: the acid diffuſed through its ſubſtance being by theſe means decompoſed and converted into pure air, with a velocity not equalled by that of any other exploſive matter whatever.

The exploſion from lead ore and ſpirits of nitre, mentioned by Dr. Prieſtley, page 68. Vol. ii.—that from zinc and the arſenical acid, obſerved by Mr. Scheele, and many others to be met with in authors, admit of an eaſy explication on the principles laid down in this and ſome of the preceding chapters. We ſhall therefore ſubmit them to the reader's ſagacity, and for the preſent take leave of the ſubject.

FINIS.

APPENDIX.

OF

LIGHT, HEAT, *and* FIRE.

THERE ſeem to be, at preſent, three leading opinions, concerning the nature of light, heat, and fire.

The firſt opinion is, that light is an element, or a body *ſui generis*; that it conſiſts of particles, of extreme minuteneſs, of perfect elaſticity, poſſeſſed of the ſtrongeſt powers of attraction and repulſion, and conſequently of the higheſt activity. That theſe particles of elementary matter, either paſſing directly from a luminous body, or reflected from the ſurfaces of other bodies, in right lines, to the eye, produce the ſenſation of light, and of all that variety of colours, of which it conſiſts.—That heat is *not* a body, but a mere quality or property, of which all bodies are more or leſs ſuſceptible; that it is produced or generated by an inteſtine and vibratory motion of the particles common to all bodies; and that this motion is producible by the impulſe of the particles of light *ab extra*, and alſo by the colliſion or friction of one body with another. That light therefore does not contain in itſelf an original principle of heat, but produces the ſenſation of heat *ſecondarily*, or in conſequence of the rapid vibratory motion of its particles, impinging upon the ſenſible parts of the body. That, moreover, it produces heat in other bodies,

dies, or, more properly, communicates to them the power of cauſing the ſenſation of heat, by exciting a ſimilar inteſtine agitation in the particles of thoſe bodies. That fire conſequently is not itſelf, any more than heat, a diſtinct elementary ſubſtance, but is the effect of light ſo modified, or whoſe particles are ſo agitated, as to produce at the ſame time, the ſenſation of heat.—This ſeems to have been the opinion of Sir Iſaac Newton; and the ſame doctrine has been of late very ably ſupported by Mr. Macquer.

According to this theory, phlogiſton, or the inflammable principle, is nothing more than the pure matter of light, fixed in, or combined with, the particles of thoſe bodies in which it exiſts, in conſequence of its ſtrong attraction to thoſe particles, and only ſeparable from ſuch bodies by a force counteracting and overcoming this attraction.

The ſecond opinion is, that heat, as well as light, is a diſtinct elementary body, having properties different from thoſe of all other bodies, as well as from thoſe of light; that its particles enter more or leſs into the compoſition of all bodies, and remain in a fixed or quieſcent ſtate, in conſequence of their attraction to the particles of ſuch bodies; that when extricated or ſet at liberty from thoſe particles, with which it was before united, by the intervention of other bodies, to which ſuch particles have a ſtill ſtronger attraction, as in

the

the caſe of friction, percuſſion, or commenſtruation, they recover, what may be called, their original or native activity, and diffuſe themſelves throughout the bodies of which they were a part: that in theſe circumſtances, and in conſequence of ſuch activity, they have the power or property of producing the ſenſation of heat, and likewiſe of communicating this power to thoſe bodies, throughout which they are thus diffuſed.—That fire therefore is not a ſimple element, but is compounded of two diſtinct elementary bodies, *viz.* light and heat, in a ſtate of the moſt intimate union or combination.

According to this opinion, phlogiſton is neither pure light nor pure heat, but is compounded of both theſe ſubſtances, intimately combined with each other, and with the particles of thoſe bodies in which it exiſts: in conſequence of which laſt combination, it loſes its activity, and becomes fixed or quieſcent in ſuch bodies.—This is the doctrine maintained in the preceding pages.

The third opinion is, that fire is in itſelf a diſtinct elementary ſubſtance; that the particles of this ſubſtance have the properties both of light and heat, or have the power of producing both theſe ſenſations in peculiar circumſtances and ſituations; that theſe particles, when impinging upon the eye in a certain quantity, with a certain velocity, and in a certain direction, produce the ſenſation of light; and that the ſame particles, when impinging

impinging upon the other ſenſible parts of the body with a certain momentum, produce the ſenſation of heat; that the ſolar rays are therefore, ſtrictly ſpeaking, not rays of light, but rays of fire; that they *produce* light as an *effect*, or *are* light as a *cauſe*, when ſtriking the organ of ſight particularly, in a particular manner; that they *produce* heat, as an *effect*, or *are* heat as a *cauſe*, when ſtriking *any* ſenſible part of the body with ſufficient force; and that when bodies produce heat without light, or light without heat, theſe different effects are to be accounted for from the different conſtitution of ſuch bodies, and the different circumſtances, in which the particles of fire iſſuing from them act; in ſhort, from the greater or leſs velocity or denſity of the particles emitted.

According to this opinion, phlogiſton is the pure matter of fire, having in its uncombined or diſengaged ſtate, the properties both of light and heat; but, when combined with the particles of other bodies, becoming fixed and quieſcent; communicating, however, various properties to ſuch bodies, in proportion to the quantity, which enters their conſtitution, and according to the different manner of its combination with them.—This laſt opinion ſeems to be that of the chemiſts in general, as far at leaſt as they have thought proper to explain themſelves on this ſubject.

TENTAMEN

PHYSICO-CHEMICO-MEDICUM

DE

TRIBUS IN UNO.

Scito fili, quod ſubſtantia agens in hoc toto mundo eſt unum, ſcilicet calor, ſive lux aut ignis.

ALPHIDIUS.

TENTAMEN
PHYSICO-CHEMICO-MEDICUM
DE
TRIBUS IN UNO.

QUICUNQUE ſubjectum aliquod tractare vult, eum ante omnia oportet, ut ſciat, de quo ſit ſcripturus. Sed de Igne conſcripturo hoc non adeo facile apparet: quia quod unus Ignem nominat, alteri nequaquam hoc nomen mereri videtur. In rebus tam valde diſſentientibus ſatius videtur in illas ſtare partes, ubi maxime inter ſe convenit. Hoc autem minime ſit inter philoſophos. Philoſophi enim de hoc, ut quandoque etiam ſuper aliis rebus dormire amant, & oculos contra lucem claudentes, ſedulo & anxie ſignum

videre poſtulant. Quærunt ſignum ſenſibile & illa negligunt, quæ maxime ſenſibus eorum ſe offerunt. Nempe philoſophus non ſenſibus ſentit, ſed ratione ſua; dum vulgus non ratione ſed ſenſibus utitur ad ratiocinandum. Nos vero malumus in rebus mere rationalibus conſulere illos, qui ratione ſua; in rebus autem ſenſitivis, qui ſenſibus utuntur. Auſcultemus igitur vulgus, præcipue cum inter hoc nulla ſit de hac re diſceptatio; ſed uno ore conſentit ſequentes dare definitiones.

I.

IGNIS *in genere*, vocatur, omne quod illuminat, aut calefacit, aut illuminat ſimul & calefacit.

II.

Quicquid priorem ſolam exhibet qualitatem, LUMINIS nomen adipiſcitur.

III.

Quod vero poſteriorem tantum monſtrat, nuncupatur CALOR.

IV.

Quod utraque ſimul gaudet dote, ita ut ambæ ſenſibiliter nobis ſe manifeſtent; IGNIS *proprie* audit. Huic autem diſtinctionis

tionis ergo per totum hoc opuſculum, IGNIS CAUSTICI nomen imponemus

Erunt forte, qui primæ harum definitionum utpote ne quidem communi ſententiæ congruæ ſymbolum ſuum adjicere recuſaverint. Sed debent hi in conſiderationem trahere, vulgari loquendi uſu lunam, ſtellas, noctilucas, phoſphoros & alias materias nullum caloris gradum ſenſibilem exhibentes a multis in numerum ſubſtantiarum ignearum recipi; quamvis ſi ab eis quæratur, num hæc putent veram Ignis naturam conſequi, fortaſſe negative ſint reſponſuri: quia his ignis naturam latiori tantum ſenſu concedunt; nequaquam vero ſtrictiori. Lectorem idcirco moneo atque rogo, ne has confundat diſtinctiones; ſed ſedulo attendat, me ſimplici Ignis vocabulo in ſequentibus pagellis ſemper intellecturum Ignem ſenſu generaliori ſumptum; & numquam de Igne vero ſive peculiari mentionem facturum, niſi addito (καυστικῷ) aut alio tali epitheto. Fateor etiam lubens hanc notionem *Ignis* minime eſſe exquiſitam, & nequaquam pro definitione abſoluta poſſe haberi; ſed cujuſcunque ſit generis, an definitio, an deſcriptio, ſive notio tantum; tamen ſi notio utilis, & ad naturam ignis inveſtigandam apta, non temere mihi videtur rejicienda: ſaltem donec altera potior ei ſubſtitui queat. Quod ad ſecundam & tertiam definitionem attinet, credo neminem me cavillaturum, quaſi negaverim

calorem

calorem lumini competere aut vice versâ, quia ex antecedente & subsequente clare patet, hæc affirmari aut negari tantum in eo, quantum sensus afficiant nostros. At si his objiciatur criteriis, utpote non sufficienter determinatis; respondeo ea esse saltem æque bene determinata, ac alia quæ nobis imposuerunt magna quidem nomina; sed quæ post multas ambages, experimenta sæpe dubia, & ratiocinia non nimis firma ad eundem redeunt, nempe sensuum testimonium; quod hic tamen non tam universaliter datur quam in casu priori.

V.

In ignis naturam inquirenti maxime necessaria videtur ejus productionis cognitio. Hanc igitur assequamur.

VI.

Productio ignis potest considerari sub duabus conditionibus, scilicet in materia, e qua; & modo, quo producitur.

VII.

Modi illum producendi, qui primo aspectu se nostris perscrutationibus offerunt, in sex classes videntur distinguendi; viz. 1. Attritus solidorum. 2. Commixtio liquidorum heterogeneorum. 3. Solutio solidorum

lidorum in liquidis, 4. Expoſitio ad aërem, 5. Fermentatio. & 6. Communicatio.

Primæ claſſis exempla ubique patent. Omnia namque ſolida inter ſe invicem contrita calorem producunt. Actioque hæc ſi per ſat longum tempus continuetur aut cum ſufficienti perficiatur celeritate in *Ignem verum* & flammas prorumpit; ratione ſemper habita ad eorum duritiem, ſed præcipue ad materiæ inflammabilis, quam continent quantitatem. Huc maxime pertinent methodus vulgaris ignem excitandi per ſilicis & chalybis conflictum; iſta Indis uſitata mutuo lignorum attritu; & illa fabris non ignota; quando auctis mallei in incudem ictibus, ferrum antea caleſcens tantum, nunc penitus excandeſcere faciunt. Lumen vero exhibent, vitra & chryſtalla ſuper ſe invicem celeriter mota. Ne de mercurio dicam quod & fluidum a plurimis habeatur; & ejus phænomena potius ad electricitatem referantur, de qua nunc tractare non eſt inſtitutum meum. Nolim etiam in medio afferre notiſſima illa ſacchari ſubſtantiarumque animalium attritu in obſcuris luceſcentium exempla; quia ex his educi magis quam produci lumen videatur. *Secundam* diviſionem probant aquæ cum alcohole, ejuſdem cum acidis concentratis, dein horum cum alcohole, ſed præcipue cum oleis deſtillatis mixtiones; quæ in his omnibus circumſtantiis calorem

lorem producunt; ſed in ultimo caſu non raro in vivas, imo & in vividas flammas erumpunt. *Tertii* ordinis exempla præbent lapidum quarundam, terrarum alcalinarum, nedum alcali ipſius in Acidis, Oleis aut Alcohole ſolutiones; quæ calorem monſtrant admodum ſenſibilem: hic tamen multo meracior datur in metallorum ab acidis præcipue concentratis diſſolutione, qui rurſus aquæ cum calce viva mixtioni cedit: de hac enim auctores non temnendi narrarunt naves & currus eâ madefactâ onuſtas fuiſſe accenſas. Huc quoque numeranda venit deflagratio ferri cum ſulphure; quæ niſi hæc prius aqua ſolvantur: nunquam accidere fuit obſervata. *Quartam* conſtituunt claſſem phænomena, quæ in acidis concentratis apparent; quum in lagenis immiſſa apertis aut ſaltem non bene clauſis, non leviter quandoque incaleſcunt; maxime autem in aluminis mineris, quæ aëri expoſitæ ſæpius ſcintillant & inflammantur; quanquam non deſunt qui fermentationem quandam foſſilem ſtatuentes, ad illam omnino hoc referre malunt: in Pyrophoro Hombergiano eundem effectum videmus produci. *Quinta* ignem producens cauſa eſt *Fermentatio*. Hæc vulgari quidem diviſione diſtribuitur in vinoſam, acetoſam, & putridam; quæ pari itidem creſcunt gradu caloris; ita ut ultima quidem aliquando uſque ad *Ignis cauſtici* geneſin procedit, non admodum raro in acervis fœni juſto humidioris exemplo; quin etiam hæc fermentationis ſpecie valde frequens

obſervatur

obſervatur *lucis* productio, ut lignorum, carnium, piſcium, &c. putrefactorum phænomena creberrima evincunt. Ultimus ignem pariendi modus fit communicatione. Hujus autem vis ad calorem ignemve cauſticum gignendum ſeu ab igne culinari ſeu a ſole proveniens neminem latet. Non vero tam, familiaris eſt ejus potentiæ cognitio, qua in linteis, chartis & innumeris aliis rebus *Igni cauſtico* admotis fulgorem luminis excitat. Alia plane methodo eandem recipiunt dotem Lapis Bolonienſis & ejus multiplices imitationes artificiales; quippe qui poſtquam ad diem apricum ſolum fuerint expoſiti, in tenebras delati Lumen per aliquod tempus undique ſpargunt. Hi autem quamvis radiis ſolaribus immediatis non egeant, ſed potius his imminuatur eorum effectus; attamen quia opus eſt ut in loco ponantur lucido, omnino ad hunc ordinem *communicationis* pertinere videntur. Huc quoque trahi poſſit vis electricæ communicatio; ſed hanc lubens prudenſque prætereo ad octavam tranſeuns propoſitionem; lectore tamen prius monito, me in hac diſtributione ad cauſas tantum immediate ignis productionem antecedentes attendiſſe, neglectis aliis magis remotis quæ autem paragraphis, ſequentibus mihi erunt explicandæ.

VIII.

Et hi omnes redigi poſſunt ad unum nempe ſolutionem. Ratio vero hujus melius apparebit in ſequentibus.

IX.

Materiam autem luſtranti patet, ſemper ineſſe phlogiſton & acidum cujuſcunque generis.

Nemo hominum, qui chemiam etiam a limine ſalutavit, perſpectis in diviſione antecedente exhibitis materiis, huic propoſitioni inficias ibit: ſi ſimul quoque perpenſum habeat, acidum univerſo aëri ineſſe, qui non tantum corporibus accendendis aut accenſis acido carentibus illud ſupplet; ſed etiam eorum, qui acidum in ſibi ipſis recondunt, incendium multum juvat. Hæc enim vero ultima etiam in vacuo Boylcano incenduntur, flagrant, lucent; quanquam hoc minus impenſe, cæteris autem ne hoc quidem evenire videmus. In prima enim claſſe cernimus particulas ferri & ſilicis contra ſe invicem in vacuo compactorum liquefieri quidem, certo generati ignis indicio, ſed nec ſcintillare nec ignem ſuum ad pulverem pyrium eis ſubſtratum communicare, etiamſi hic ſit corpus quam maxime inflammabile. Silex nimirum acidum continet ſicut & ferrum phlogiſton;

ſed

ſed acidum vitriolicum tantum, minime illud nitri, quod quia iſto in aëri habitanti, multum appropinquat, aëreum audit multis, & contra aër acidum nitroſum in ſuo ſinu fovere dicitur. Certe acidum nitri multis gaudet dotibus, quibus carent cætera, & quas ſolas in aëre obſervamus. Inter has præcipuum tenet locum illa ad ignem expanſilitas, aut, ut aliis nuncupatur, elaſticitas; qua illius contactum effugere videtur, dum illum nutrit & fovet (*); etiamſi fatendum ſit eum vel hic e longinquo tantum aërem imitari. Hac tamen facultate nullum aliud fruitur acidum, cujuſcunque ſit generis; ſaltem nobis non manifeſtatur. Ergo ſulphur quod ex acido vitriolico & phlogiſto conſtat antliæ pneumaticæ commiſſum *communicatione* quidem accenditur, & flagrat; ſed multo debilius quam in æthere aperto; quin & hoc non fit, cum in vaſis aëris introitum coërcentibus *ignis cauſtici* contactum immediatum non experitur, tunc enim, nequaquam in flammas converſum, ſub ejus forma propria ſublimatur: dum pulvis pyrius, qui nitrum in ſe recipit, eodem modo tractatus eoſdem plane (ſi detonationem excipias) ac aliter ſolet, producit effectus. Nec deerit detonatio ſi modo quantitatem ſatis magnam accipias, Boyleo & Hauksbejo teſtibus. Sed nec olea eſſentialia, quæ cum

(*) Stahl. fundamenta Chymiæ pars III. p. 221. hanc graphice & energetice vocat, die aus einander Treibung und aus einander Treibende Spannung.

acido perpauco tam ſtupendam copiam Phlogiſti recondunt, ullo modo ad Inflammationem in vacuo deduci poſſunt: dum Phoſphorus, qui magna parte ex acido conſtat, magis etiam hic quam aëre aperto lucet. Sic vitrum in hac machina æque ac alias attritu effulget, quia nempe acidum copioſum in ejus compoſitionem intrat. Ex his colligi poteſt ad ignem cauſticum generandum aut ſuſtinendum requiri acidi qualiſcunque præſentiam; ſed præſertim huc facere illa in nitro aut in aëre reperta, quæ non ſolum chemicis ſed & mechanicis viribus hic agere videntur; nimirum motu ſuo perpetuo ignis particulas agitando, comprimendo, inter ſe miſcendo. Sed quoniam non mihi latet hujus in aëre exiſtentiam a quibuſdam, utut numero quidem paucis, chemicis diſputari; non abs re alienum fore duxi, quædam argumenta contra horum objectiones hic afferre, illa vero, quæ ad hanc ſententiam ſtabiliendam adduci poſſint, parum curans; quippe quæ ſatis jam ſunt numeroſa, & quidem rem ſedulo perpendenti nunquam videntur exhaurienda, quæ in iſtum finem ex phœnomenis quotidianis huc trahere liceret. Primo negant quidem notiſſimam illam ſalis Tartari in Tartarum vitriolatum mutationem, poſtquam ad aërem expoſitum fuerit per aliquod tempus; affirmantes ſibi in hoc experimento inſtituendo nihil tale accidiſſe; hoc poteſt verum eſſe, & ſimul fidem illis ſtare, qui contrariam ſuſtinent ſententiam. Duo enim poſſunt hoc experimentum turbare: & expoſitio

ſitio ad aërem nimis humidum, ubi adeſt multum aquæ & acidi parum: & ignis ad evaporationem neceſſarius, qui ſe acido immiſcendo & id ſaturando, ejus cum Tartari ſale unionem impedire queat. De hoc autem plura in ſequentibus. Sed & metallorum in aëre eroſiones ab acido ejus provenire negant; quia nempe has imitari nequeunt: ſi enim in acidis ſolvantur metalla, hæc ſunt iterum in aqua ſolubilia; tamen exempla habemus ubi hoc aliter accidit, ut in antimonio Diaphoretico, Mercurio minori acidi copia ſoluto, ceruſſa, & aliis videre eſt. Hæ autem ab aëre eroſiones non tantum ab acido valde diluto fiunt, ſed & ipſo cum aqua intime mixto; non eſt ergo mirandum, idem hic non fieri, ac evenire quidem poteſt in acidis aqua de induſtria ſolutis, & ſuper metalla affuſis; nempe acidorum præcipitationem & metallorum plenariam ſolutionem. Si enim natura agit chemicum, quo nil certius, nil univerſalius videtur; forte non adeo abſonum foret, ut credas illam eſſe chemicum eis meliorem & aliquando illius operationes operationibus earum fieri accuratiores. Nequeo quin his addam; Cl. SPIELMANNUM non adeo ſolutionum quarundum per deliquium, ut aiunt, factarum rationem fuiſſe miratum, ſi quando de aqua in aëre contenta ſimul quoque de acido ibidem habitante cogitaſſet, aut illius exiſtentiam ſaltem fateri voluiſſet: multa enim horum phœnomenorum, quæ, ut hic recte obſervat, nullo modo ab aquæ in aëre volitantis

attractione

attractione ſunt explicanda, facile ab acidi commixtione explicantur. Sic, cur Tartari ſal Fixus tam cito in aëre diſſolutionem patiatur, cum ſales alii, (qui tamen acidum in ſe habent & ea de cauſa facilius in aqua ſolvuntur) hanc multo difficilius ſubeant; e ſua cum acidi affinitate & hujus iterum cum aqua in aëre nexu non ægre evolvitur. Eadem eſt ratio ſalis communis aliquoties fuſi, atque ita ex parte acido ſuo privati, deliqueſcentiæ; itemque multorum aliorum hujuſmodi phœnomenorum, quæ non ſunt hujus loci & idcirco hic omittenda. Si nunc quis materias ad ignis confectionem aptas attente conſpiciat; nullus dubito, quin mihi lubens aſſentiatur, in iis cunctis hærere & acidum & phlogiſton; ſi autem modos illum gignendi varios animo evolvat, præcipue iſtam frictionis methodum cum illo alio in tertia claſſe exemplo, ubi alcali neceſſarium videtur ad motum concitandum trahendo acidum, ita ut cum phlogiſto magis exquiſite miſceatur; is videbit omnes hos modos in unum conſpirare finem, nempe duarum ignis materierum ab aliis rebus heterogeneis ei evolutionem & intimiorem mixtionem; atque idcirco optimo jure ad unicum poſſe redigi, nempe ſolutionem.

X.

Et hoc quidem varia proportione (ſaltem varia proportione conjungi) prout *lumen*, *calor*, aut *ignis cauſticus* producuntur.

XI.

XI.

In *lumine* acidi quantitatem longe ſuperare quantitatem phlogiſti.

XII.

E contra in *calore* phlogiſton abundare reſpectu acidi.

XIII.

In *igne* autem *cauſtico* horum proportionem eſſe magis æquabilem.

Harum propoſitionum demonſtrationes ſimul & ſemel dare præſtat; quandoquidem ab alterutro invicem pendeant, atque ex una data aut demonſtrata facile cæteræ eruentur. Pro exemplo ultimam hanc ſumam; ita ut ſtabilita hac, aliarum comparationes denuo inſtituantur: atque eum in finem ſingulas, quas ſupra conſtitui claſſes, iterum viſitare & relegere conducet. Primo quidem *Fricti*one cernimus non ſolum in aëre ſed etiam abſque hac ignem ex ſilice & ferro educi: nec mirum; cum ſilicibus acidum ineſſe cognoſcimus facili in lacte ab iis coagulato experimento; quando autem abeſt aëris & acidum & motus, non gignitur Ignis Cauſticus; nihilominus ferrum perfecte funditur, imo ex parte ſcorificatur. Neque hoc altero mirabi-

lius

lius videbitur ei, quem non fugit nil aliud ad metallorum coheſionem deſtruendam requiri, quam phlogiſti in illis contenti ſolutio; hæc autem optime fit acidi per vim magnam colliſionis ex partibus duriſſimis terreſtribus evolutione, quod phlogiſto ferri itidem educto ſe admiſcens calorem generat; & ſic oritur illa ſolutionis ſpecies, quæ Fuſio vulgo audit. GAUBII autem noſtri obſervatio verum ſulphur (*) hic inveniri monſtrat fuſionem hanc eſſe admodum imperfectam, ſicut ex calore tantillo expectari debet; & ſimul non paululum Theoriam hanc totam confirmat; quandoquidem ſulphur nil aliud exiſtit, quam ignis purus; ignis tamen dormiens, & defectu veræ mixtionis chemicæ nondum in actionem provocatus. Hanc probat non ſolum opinio antiqua, ſed multo melius ejus analyſis chemica cum effectibus ſuis collata. Stahlius enim id ſolis acido & phlogiſto, paululum terræ excipias, conſtare, & ſyntheſi & analyſi pulchre monſtravit; & ejus in vacuo accenſio & ſine fumo diſſipatio luculenter oſtendit ignem cauſ-

(*) Cl. NOLLET ſupponit ſulphur ipſum inheſſe lapidi & ab eodem omnia hæc phænomena derivat. Si de pyrite agatur hoc omnino eſt verum, ſed de ſilici jure poteſt dubitari, verum ſive pyrites ſulphureus ſive ſilex acidum ſolummodo continens huic operi abhibeatur, ad eundem redit: nec differt multum explicatio, niſi majores effectus a ſulphure quam a ſimplici acido non temere expectari videntur; hi autem dantur, notante MUSSCHENBROEKIO, & in hoc caſu & in illo altero, ubi durior & majori phlogiſti copia gaudens chalybs ferro ſubſtituitur.

ticum

ticum ipſum ex eadem conſtare materia. Nec minus juvat hunc fidum naturæ operum explicatorem non hic tantum ſed aliis quoque prælectionum ſuarum locis huic ſententiæ & inſcium favere; quam eundem præceptorem ſalutare, ex cujus ſchola prodierunt præcipui quivis artis noſtræ Profeſſores. Non ſane opus eſt ut in omnibus ſubſtantiis tam accurate examinandis immorer; quis enim ignorat & acidum & phlogiſton copioſe ineſſe lignis, aut ſulphur ipſum ferro, ex cujus minera extrahitur: in utraque autem harum ſubſtantiarum calorem aut ignem vivum produci ſecundum frictionis violentiam & continuationem neminem latet. Sed & chryſtalla quæ minimum certe, ſi aliquid materiæ ignis, ut vocatur pluribus, in ſubſtantia ſua involvunt; hunc tamen evolvunt, quando ſuper ſe invicem atterantur. Qualem vero? nimirum ſpeciem illam quam lucem nominamus: in qua phlogiſti ad acidum ratio per Hypotheſin admodum eſt minuta. Ita quoque hic, qui datur, ignis non tantum effectibus ſuis ſe lucem eſſe probat; quippe cujus calor non ſit ſenſibilis; ſed & nec ſe huic ſyſtemati præbere in cauſis ſuis conſpectus recuſat. Neminem enim negaturum puto, acidi magnam hic adeſſe copiam; & quanquam ſint qui negant chryſtalla ullo modo phlogiſton continere, innixi valde infirmo nitri cum illis non detonantis experimento, tamen hi etiam vaporum ſulphureorum in aëre exiſtentium a Boyleo & Halesio adductas de-

monſtrationes refutare nequeunt. Ergo his nihil moratus, *ſecundæ* harum diviſionum, nempe *commixtionis liquidorum* examen adoriar. At omnes ibi recenſiti modi eodem fere ordine, quo locantur, in ſuis effectibus creſcunt; duo poſteriores nulla egent explicatione; duorum priorum ratio non eſt tam aperta, prima tamen non ita obſcura, effectuum, quos edunt, (turbatio ſcilicet & remixtio partium conſtituentium) non ignaro, & ſimul cogitanti cum copioſo illo phlogiſto & acidum quoque admiſceri. Eo autem major datur effectus, quo meracior eſt ſpiritus; quoniam quo minorem continet aquæ copiam, eo major eſt acidi ad aquam trahendam niſus, ergo eo major motus, mixtio, & calor. Secundum mixtionis exemplum non ita facilem admittit explicationem: tamen hæc habebitur, ſi violentum acidi fortiſſimi conatum ſitim ſuam aquæ extinguendi perpendamus; hoc enim quæcunque aut aquæ aut acido inſit, minima phlogiſti particula per vim motus iſtius intime cum eodem acido concentrato miſcetur. Sed vix negari poteſt & in acido & in aqua hærere aliquantulum de hac fere univerſaliter diſtributâ materiâ; atqui ad calorem ciendum cum motu tam acri & acido tam puro quam paululum hujus quidem ſufficit. Nam in omni æqualium caloris graduum geneſi obſervandum, ubi deeſt fere materia ea ratione augeri motum; & ubi ambo fere deficiunt, eo magis evolutas eſſe ignis materias. Hoc monito ad proxime ſequentem tranſeo claſſem;

claſſem; quæ quoniam metallorum phlogiſto refertorum, ſalium alcalinorum hoc ab igne adeptorum, & terrarum hæc imitantium, cum acidis conflictus præcipue ſiſtit, examen accuratius & peculiare non meretur; ſed non ita prætereundæ calcis vivæ & ſulphuris ſolutiones; de priore autem non eſt quod multa dicam; quippe de qua Hypotheſes adeo variæ & multæ jam ſint prolatæ, ut videatur æque ſupervacaneum ac arduum huic rei lucem afferre. Experientia autem auctorum loquitur arduum eſſe hoc opus, & Lectorum, non adeo fore ſupervacaneum. Donec ergo melior prodeat explicatio; monere liceat, hujus ſubſtantiæ in forma ſua mutata geneſin, nos docere multum materiæ igneæ huic ineſſe; ſed quodnam genus, aut quomodo agat, altioris eſt indaginis; & videtur majorem poſcere conſiderationem, quam aut tempus aut hujus diſſertationis limites permittunt. Liceat igitur hanc demonſtrationis partem ad alios ſcriptores aut ſaltem ad tempus & locum magis opportunum relegare. Deflagratio ſulphuris cum aqua in paſtam redactorum, a ſolutionis & chemicæ attractionis principiis repetenda: aqua etenim partem acidi ſulphurei diſſolvente, hoc avide excipitur a ferro, cum cujus phlogiſto confligens, calorem edit ſatis validum ad ſulphuris inflammationem ciendam; & hoc eo facilius quam non datur aquæ copia ſufficiens ad motum illum incipientem ſuffl aminandum. In *quarta* claſſe, phænomena acidorum aëre attracto incaleſcentium

ad ſecundum ſecundæ claſſis exemplum omnino referri debent, quippe quæ fiunt ab aqua in aëre ſoluta. Sic ille ab HOMBERGIO dictus phoſphorus, qui ex Calce Viva & ſulphure conſtat, aëris humido cum ſua calce efferveſcente, inflammatur vi caloris ſulphuri communicati. Eadem fere videtur minerarum aluminis ardentium ratio. *Fermentatio* quinto loco venit tractanda, quæ quoniam nondum a virorum doctorum experimentis ſat lucis accepit, hic levi tangenda calamo. In hac STAHLIUS duo conſiderat, motorem & mobile. Motores autem iterum duo prodeunt, aër & ignis, quorum agendi modus etiam bipartite, mechanice ſcilicet & chemice, conſpici debet. Et cum in omni fermentationis materia inſunt & acidum & phlogiſt ; non eſt mirandum, quod hæc a viribus *motorum* prædictis ita miſceantur, ac vario modo combinentur, ut non tantum *calorem*, ſed, & abſente fere aqua, ſic ut in illo fœni exemplo, *ignem vivum* producant. Nec magis mirandum, oriri ex harum duarum *mobilis* partium combinatione aut proportione diverſa materiam luceſcentem: quod ſane fieri videtur, quando particulis phlogiſticis per longam moram & continuam caloris actionem maxima ex parte expulſis, quæ manent, per eadem media motu perpetuo adjuta prorſus ſubigantur, & intime cum acido fixiori, quod non adeo facile abigi potuerit, coaleſcunt. Saccharum autem, quod ex unione acidi ſalis cum oleo exſurgit; etiam in vacuo nitet, ſi teſte BOY-

LEO

LEO frictio ei accedat. Hinc patet natura Phoſphororum naturalium; ut quoque Phoſphori illius ex urina confecti; qui, quamvis arte ſit productus, tamen quia ratio ejus combinationis ſatis eſt obſcura, malui ex recenſione in integrum omittere, quam de re non ſatis manifeſte incertas Hypotheſes confingere. Luculenter vero apparet ex phlogiſto & acido copioſo componi; quod in eo acidum nitri imitatur, ut minime aëre egeat ad inflammationem ciendam; in vacuo enim magis quam ſub dio lucet, etiam ſi multo pallidiori gaudeat flamma; indicio particulas phlogiſticas majoris attritus vel & forſan acidi copiæ defectu non adeo cito nec pari paſſu cum acido eſſe evolutas. Alii tamen phoſphori naturales, excepto Adamante, aëre orbati nil lucis repandunt. De maris fluctibus nocte lucentibus multum diſputatur, ſed quoniam conſtat Bitumen in illo inveniri, nil hæreo & hoc phænomenon a ſimili derivare cauſa; ita ut Bitumen cum aqua illa ſale referta, & continuo motu agitata intime combinetur, & ſic Phoſphori ſpeciem exhibeat. *Communicatione* omnia nobis cognita corpora calorem concipere poſſunt: ſed multa & fluida & ſolida exiſtunt, quæ ignem ſua ſubſtantia fovere recuſant: inter ſolida enumerantur ea tantum corpora, quæ nullum continent phlogiſton, aut, ut accuratius loquar, quæ hoc nullis ſignis oſtendunt; abſurdum enim foret credere aurum & argentum hoc carere principio, quia ob arctos forſan poros id non evolvant.

Atque

Atque idem dici poteſt de cæteris, materiis igni refractariis; hæc tamen cuncta igniri, ſive *igne cauſtico* perfundi, æque ac alia, ſeſe apta præbent; quanquam ceſſante ignis ab extra in illa actione, ceſſant ſtatim & in illis ſigna ignis cauſtici præſentis, & gradatim calor omnis avolat. Fluida autem non inflammabilia ne hoc quidem præſtant; ſed aut igne cauſtico immediate iis applicato in auras abeunt, aut hunc minuunt, ita, ut ne quaquam ardeat, ſed tantum caleſcat. Et hæc ſunt quæ nil aut parum Phlogiſti involvunt. In iis autem, quæ citiſſime inflammari poſſunt, ſi corpus flammans immergas; hoc, notante BOERHAAVIO, ſine mora extinguitur; ſed ſi eorum ſuperficiem ſolam illo tangas, extemplo inflammatur & ardet, quamvis infra hanc calor tantum datur, flamma ſuperficiem ſemper affectante. Quæ autem lumen attrahunt ſubſtantiæ factitiæ, atque iterum, pro aliquo ſaltem tempore refundunt, compertæ ſunt omnes conſtare ex acido cum Terra calcarea conjuncto: hæ, poſtquam igni valido expoſitæ fuerint, quo igneis particulis cum acido prius ab illa terra calcarea fixo ſe miſcentibus imbuuntur, lucem avide & celerrime inhauriunt ob materiæ luminis ad ignem ibi contentum affinitatem. Ignis autem tandem deſtrui ſolet atque calcinatione iterata reſtaurari debet; claro indicio lucem hunc elicuiſſe ex corpore, cui antea junctus fuit. Sed & in tenebris diu detentæ non amplius lucent niſi per longum tempus lumen iterum imbiberint,

quod

quod æque clare oſtendit, materiam lucis majori copia adhiberi debere, ad illam *ignis cauſtici* luciferam partem reſtituendam. Denuo quoniam Lapis Bononenſis in vacuo non nitet, evidens ſit & lucem quandoque aëris facultate motrice egere. Hic autem quæri poteſt, quomodo ſit ut aqua in olla contenta calefiet, immo vi caloris ebulliat, ſine ullis luminis in eam penetrantis ſignis. Cui reſpondeo ignem cauſticum quia lux non poteſt per metalla aliaque corpora opaca tranſire, decomponi videri, & lumine quidem partim reflexo partim in ſubſtantiam metalli abſorpto, calorem tantum, ſive partem ignis craſſiſſimam, per id penetrare. *Lucem* autem *calori* longe præire ſubtilitate, quamvis media quamplurima calori facillime patentia illi ſint omnino impervia, ex hoc manifeſtum redditur, quod radii ſolares, vel etiam ii a minima candela provenientes, ad infinitum fere ſpatium percipiantur, cum calori ab iiſdem procedenti anguſti admodum ſint limites. Calorem vero præcipue ex Phlogiſto conſtare, oſtendit corporum & præcipue vegetabilium in vaſis clauſis combuſtio; quæ cum & proprio, & illo in aëre degente acido careant, nec rubent, nec ſcintillant, nec ulla ignis vivi ſigna edunt, a Phlogiſto in eorum partes externas (quaſi ſolvi cupiente) expulſo, nigricantes, in eodem ſtatu per annos perdurant, etiam ſi Gehennæ urſeris igne. Hinc quoque alterius, in aqua bulliente phænomeni ratio eruitur. Mirantur

multi

multi ſe catinum ferreum, mox ab igne ereptum, & liquido fervido repletum, manibus tuto geſtare poſſe; quando idem, cum fluidum ibi contentum jam bullire ceſſaverit atque idcirco non ita calidum eſſe debet, miſerrime manus, ſi admoveant, ſit afflicturus. Ratio autem in hoc ſita eſt; quod ignis motu ab infra accepto, ad ſuperiora tendit; hic cum magna ſatis datur copia ad liquorem in bullas elevandum, perque eas aufugiendum, vaſis fundum tantummodo tranſit nec ſedem ſuam in eo ponit, ſed quando non amplius ab extra urgeatur, cum motus communicatione ceſſant quoque ejus vires: aquâ ergo tranſitui ejus libero reſiſtente, undequaque ſe expandere conatur, atque ita vaſis fundus plus caloris quam antea accipit. His expoſitis, liceat jam hujus ſubſtantiæ mirabilis, definitionem realem publico examini offerre.

XIV.

Itaque Ignis, genetice definitus, eſt *ſolutio chemica phlogiſti in acido facta.*

Quanquam hoc ex antecedentibus abunde pateat, ad hanc tamen theoriam roborandam non inutile erit alia adhuc afferre exempla: & denuo licebit, concluſiones aliquas deducere a natura ignis ita cognita, ut tam utilitas ac hujus ſententiæ veritas magis appareat. Et primo quidem optime illam confirmat Ill.

Ellerī

Ellerı (*) obſervatio, ſcilicet, ſe in aqua, quam ſoli expoſuerat & acidum & phlogiſton reperuiſſe. Et ſane ratio credere jubet, tale fluidum non poſſe ex altero tam facile exire, ut non reliquias aliquas in illo depoſuiſſet; quin & aquæ ad acidum notiſſima attractio non ſinit cogitare, ignem abſque ulla decompoſitione ex illa avolare poſſe totum; quocirca non paululum ſuſpicor minime eſſe puram tam jactatam illam quæ diſtillatione elicitur aquam: & quamvis forte parum acidi contineat ob ignem caufticum non immediate applicatum, tamen ſuſpicio inhærentis phlogiſti non videtur omnino vana. Deinde in lignis, ſed præcipue in Lithanthracibus accenſis, cernimus flammam ſemper initio naſci, poſtquam autem acidum, quod & in deſtillatione ſemper primum prodit, omne in auras abierit, & nil niſi phlogiſton cum terra conjunctum manet, flamma ceſſat & lignum intenſius rubet; minus datur luminis, plus caloris. Ita & igne aperto combuſta corpora in cineres abeunt, in vaſis autem clauſis in carbonem; quia phlogiſton, jam ab acido quocum antea junctum erat relictum, nec per ſe avolare aptum, in terra manere cogitur, nigro ejus colore ſe monſtrans: ſed hoc ſolvitur & defertur ab aëris acido, ſi modo ei aditus detur. Ex his ſatis ſuperque patet, ignem eſſe veram ſolutionem chemicam; & ſub iſto af-

(*) Memoires de Berlin année 1748. Diſſert. pour le formation des corps.

pectu viſum, non eſt, cur miremur eum tam frequenter attractiones turbare chemicas majore affinitate ſua. Exempla hujus rei cuique, etiam artis ſpagyricæ tyroni, ubique obviam eunt. Unum aut duo tantum depromam. Aqua ſatis largam nitri copiam diſſolvit calefacta, ſed eadem hæc aqua refrigerata ad fundum præcipitat maximam nitri, antea recepti, partem, nec niſi ſextam circiter in diſſolutione tenebit. Cremor Tartari autem abſolute aquam bullientem poſcit ut in ea ſolvi queat. Nonne videmus hic calorem chemicis agere viribus, & quia ex phlogiſto præcipue conſtat, fortiori ſua attractione acidum exquiſitius adunare aquæ? ſicque ipſa in aqua ſoluta, ſolutam quoque tenere ſuperabundantem ſalem? Sed &, Ill. HAHNIO (*) obſervante, pleræque aquæ fontanæ dum aliquamdium ebulliant, multum materiæ calcariæ deponunt; & internum lebetis parietem quodam quaſi tartaro incruſtant. Dein, rogat, annon igitur calor vincula diſſolvit, quibus aqueæ & terreſtres particulæ colligatæ erant? An potius (pergit) ſtatuemus vi caloris ſubtilem materiem ſalinam, quæ terram aquæ conjunxerat ſenſim ſenſimque diſſlari? Et ob hanc cauſam terreas particulas, ab aqua ſimplici non ſolvendas, cadere? Me ſane judice huic ultimæ tribuendum eſt cauſæ, calore acidum (quæ verosimiliter hic ſolum datur vinculum) abſorbente, & ita

(*) Vid. Diſſertatio de Igne Johannis Bernd Bicker. Trajecti ad Rhenum 1765.

omnino

omnino deſtruente. Et quidem, cum ignis ſit ſolutio vera, imo forſan ſalis nomen mereatur, ratio ejus condenſationis, uti vocatur, non eſt adeo obſcura; quamvis eum concentrari potius dixerim: obſervatio enim vulgaris ignem robur & vim accipere, non tam a parte corporum inflammabili, ſed potius ab ea quæ inflammari & cremari nequit; ab hoc ſolo provenire videtur; quod ſal iſte craſſis his materiebus, ut diſſipari queat, impeditur, & ab aëre diluente defenditur. Ex eadem conſideratione eruitur quid aqua ex Æolipila aut aliis modis in ignem adacta ad eum augendum facit; & forte omnis vis flammæ quæ in lampade parvulo tam valida exiſtit, quando huic per tubulum coarctatum afflatur, ab ejus concentratione eſt derivanda. Notandum enim ignem tam a ſalibus quam a cunctis aliis adhuc cognitis ſubſtantiis in hoc differe, quod nulla ad terræ centrum vi determinetur, ſed per omne ſpatium ſe diffundere affectat. His demonſtratis ad corollaria quatuor ſequentia, Phyſicam, Chemiam, Phyſiologiam & medendi artem ſpectantia, probanda me accingo.

Hinc tempeſtatum, viciſſitudinum, nec non fulminis, aliorumque meteororum igneorum cauſæ, quam optime conſpiciuntur.

Frigus non eſſe meram caloris privationem luculenter demonſtrarunt multi neoterici auc-

tores: & quamvis non neceſſe ſit, ut cum horum quibuſdam illud ſpiculorum aut forformam aut effectum habere credas; tamen eſſe quoddam ſal acidum ſui generis multa cogunt fateri: & ſane qui aliquando hyberno tempore vento Boreali obviam ivit, facieque ſuo aëri expoſito impetum ejus accepit, non hoc forſan negabit. Acida enim cuti noſtrò applicata eandem fere creant ſenſationem, ut quivis experiri ad libitum poteſt; nec aut hic aut in aquâ congelatione opus eſt, ut ſpiculorum actionem ſupponas; nam & nix & glacies præ ſe conſtanter ferunt ſpeciem cryſtalliſationis admodum regularis, ſed ad hanc efficiendam ſalia adeſſe debere nemo ignorat; atqui hæc ſalia eſſe acida argumentis fere irrefragabilibus oſtendunt probatiſſimi phyſices ſcriptores. Non igitur mirum, ſi ſole radiis directis terram feriente, omne quod ibi ineſt frigus expellatur, & in altum aſcendere cogatur, ubi atmoſphæram ſummam multum frigefacere oportet: unde grandinis, imo nivis, in medio æſtate deſcendentis, ratio clare perſpicitur; ſed & ſol idem vapores phlogiſticos ex omni terræ ſuperficie attrahit, diſſipat, atque calore ejus aſcendere etiam cogit. Luculenter autem patet hos ad meteora ignea formanda eſſe aptiſſimos; & ſi ad eandem altitudinem progrediuntur, ac vapores iſti frigorici, qui præcipue ex particulis nitroſis conſtare videntur, manifeſtum eſt, horum cum illis conjunctione tonitru & fulmen facile poſſe produci. Hoc autem fit adhuc manifeſtius,

quando

quando in mentem venit, phœnomena hæc in regionibus calidis longe dari frequentiora, & quidem æſtivo aut autumnali tempore præcipue evenire, juxta ſolis occaſum, quando hic jam per totam diem terram radiis ſuis calefecit. Circa idem quoque tempus non admodum inſolitæ ſunt, ambulonum, ſeu ignium fatuorum apparitiones, quæ nil ſane niſi vapores inflammabiles exiſtunt; hi autem ex pinguibus locis maxime orti, ad exiguam quidem a ſolo diſtantiam elevantur, ab aëre corripiuntur, atque ita ignei facti ad ventorum libitum huc & illuc deferuntur, & aliquando manu arrepti, teſte Roberto de Fluctibus, iterum in liquorem pinguem palpabilem redeunt. Sed hanc doctrinam maxime illuſtrant efferveſcentiæ (ut vocantur) illæ frigidæ; ubi ignis a particulis iſtis frigorificis ex ſalibus expellitur, vel (ut chemici loqui amant) præcipitatur. Exempla apud auctores ſcatent, nec deſunt quoque vaporum ex his præcipitationibus aſcendentium, etiam ad ſenſus & thermometrum calidorum. Et ex his elici poſſunt, cauſæ frigoris a variis liquoribus in Thermoſcopium producti, cujuſmodi phænomena quamplurima (quæ tamen evaporationi tribuit) in actis phyſicis Edinenſibus memorat Cullenius iſtius Academiæ illuſtris Profeſſor; & quorum ſimilia in Commentariis Academiæ Petropolitanæ, jam notavit Cel. Richmannus. Nec ratio reddi poteſt, cur hyeme optime radios ſolares ſpecula reflectant; ni concedas, calorem a frigore e metallo expulſum

pulſum ad ignem ſolis attrahendum & abſorbendum impediri, nam quæ ex auctis magnitudine poris derivatur explicatio, non refutari meretur. Denique credo ex bene perſpectis & perpenſis naturæ univerſæ phænomenis, nos fateri oportet, a calore & frigore, perpetuo inter ſe debellantibus, & ſeſe mutuo e loco expellentibus, omnes tempeſtatum viciſſitudines, & præcipua aëris miracula produci.

Hinc explicari poteſt cur metalla, & aliæ quædam ſubſtantiæ plus ponderant poſt *ignis cauſtici* in illis actionem.

Metallis cunctis, lapidibus cretaceis, cæteriſque ſubſtantiis, quæ pondus ſuum ab igne adauctum habent, maximam competere cum acidis affinitatem, nemo ignorat; hanc autem vel illa, quam cum phlogiſto oſtendunt, eſſe majorem, non omnibus compertum eſſe credo: ſed etiam abſque igne metalla ab acidis in calces vertuntur, h. e. ab eis phlogiſton præcipitatur, quum ad principium hoc inflammabile (ut audit) reſtaurandum, & acidum expellendum fuſione omnino opus ſit, nempe ignis actione fere admodum notabili. Ergo non temere videtur poſſe concludi, metalla, ſeu potius terram metallicam magis acida attrahere quam ea vivificans (ut ita dicam) principium, phlogiſton. Hoc autem conceſſo, in apricum extemplo prodit metallorum aliorumque ab igne calcinatorum ponderis adauc-

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ti cauſa. Trahit nempe terra iſta acidum *ignis cauſtici* in illam ut plurimum reverberati, quod e ſuo loco indigenum maxima ex parte pellit phlogiſton. Simplici autem calore adhibito, quia tam parva ei ineſt acidi portio, non adeo ſubita datur præcipitatio, ſed gradatim fit, atque ita occaſionem præbet, phlogiſto ſe partim in ſuam propriam matricem figendi; huic autem minori actioni multo quoque minor accedit effectus. Calcinationes enim ab igne lentiori aut non reverberato factæ, ſemper obſervatæ fuere minus præbere ponderis, quam illæ, quæ hac methodo fuerunt inſtitutæ. Quid vero aptius ad pondus conciliandum, quam acida non minime certe concentrata, omniumque liquidorum graviſſima? nec plures quam duo cognoſcuntur modi ad hanc operationem efficiendam: atqui hi ſunt ſolutio in acidis, & ignis; ſed quoniam eoſdem fere dari cernimus effectus, multum differre etiam non debent cauſæ. Sane, ſi ignis infuſione, præcipitatione, & aliis operationibus ſpagyricis effectus contemplemur, inveniremus forſan maximas in attractione turbas & mutationes improviſas ab igne, uti corpore chemico, provenire; & ſi hujus in his rebus efficaciæ debitam impertiremur attentionem, multorum in chemicis phænomenorum, quæ nunc latent, eruentur cauſæ; atque forſan non ita vanæ forent iſtæ affinitatum Tabellæ quarum adhuc evulgata ſpecimina, plus ad ingenii oſtentationem, quam ad veram utilitatem, videntur confecta; & quidem, monente perſpicaciſſimo

caciſſimo GAUBIO, plures exceptiones quam regulas ſiſtunt.

Hinc quoque patet, natura caloris animalis, & uſus reſpirationis.

Acidum in ſanguine inveniri teſtantur omnes Phyſiologicæ rei ſcriptores; de parte ejus phlogiſtica ſive globulis rubris non eſt neceſſe, ut hic ſermonem faciam. Sed reperiit Cel. HOMBERGIUS hoc majori copia in junioribus dari quam in adultis, claro indicio motum vitalem id gradatim deſtruere, & quia adeo diverſa in ſanguine exſtant principia, cum horum aliquibus miſcere. Sed quæri poteſt, qua ratione acidum, continuo particulis phlogiſticis admiſtum, & quaſi abſorptum, iterum pari paſſu ſuppeditetur? duæ quidem, tantummodo in ſanguinem apertæ ſunt viæ, illæ nempe pulmonum & vaſorum chyliferorum. Per harum ultimam, materiam phlogiſticam globulos rubros efficientem intrare omnibus eſt notum; ſed non ita certum eſt acidum cum illis eadem incedere via: hoc quidem illo involutum per vaſa quandoque ſeſe inſinuando perreptare & ratio & experimenta ſuadent; ſemper autem ineſſe chylo, minime conſtat. Sed aëris acidum cum ſanguine in pulmonibus miſceri omnia docent præcipue autem coccineus ejus in vena pulmonari color, quem etiam in omnibus arteriis, excepto pulmonari ſervat gradatim tamen in purpureum iſtum, qui venis propius eſt, colorem, ut illas appropinquat,

pinquat, degenerans. Neque hic affirmare velim, ſanguinem in pulmonibus calefieri, quippe cui contrarium evenire, multi auctores, & inter illos Cl. SAUVAGESIUS valde firmis probarunt argumentis. Sed quamvis ſanguis in iſtis viſceribus diluetur, imo notabiliter refrigeretur; nequeo tamen, quin putem, reſpirationem calori animali inſervire ſecundario quamvis uſu: aëris enim, aut ſaltem acidi ejus partem illam quæ in pulmonibus non ſubigitur, per circulationis vim in omnes corporis partes deferri, atque ita gradatim ſanguine miſceri, non adeo a veriſimilitudine abhorret, & quidem ad eum a nimia ſpiſſitudine conſervandum, ſed maxime ad inſtantem perpetuo putredinem arcendam, omnino neceſſario videtur. Sed his altioribus ingeniis relictis, ultimum corollarium expedire propero.

Inde cur acida in febribus proſunt, & cur extravaſatum ſanguinem attenuant, ſolvunt, evidens apparet.

Stupendam hujus univerſi fabricam contemplanti patebit, magnum ejus auctorem omnia ita ordinaſſe, ut cuique ſuus modulus, ſua menſura accuratiſſima tribuatur. In nihilo autem magis apparet, quam in pulmonum noſtrorum mirifica conſtructione, qui, ut ſupra demonſtrare conatus ſum, præciſe aëris quantitatem ad calorem naturalem ſuſtinendum idoneam inhauriunt. Sed corpore noſtro febribus ardentibus vexato, fruſtra tentamus calo-

rem excedentem pleniori & frequentiori aëris inſpiratione temperare; & quamvis hujus purioris & frigidioris liber uſus ad eum finem multum conducat, atque idcirco temere ac abſurde ægris negatur: tamen hunc non ſufficere, experientia docet, & optime norunt medici periti, qui acida medicamenta, copia pro re nata majori aut minori, injicere ſolent, & iſtâ ſolâ fere methodo peſſimos febres ardentes, putridos, &c. feliciter ſæpius curant. In Ecchymoſibus vero ad ſanguinem extravaſatum ſolvendum, atque ita ut vaſis reducatur aptandum, acida pari ſucceſſu externe applicantur, præcipue ſi ad vaſorum conſtrictionem impediendam cum oleis immiſceantur. Ratio autem horum ex antedictis ſatis fit manifeſta: anne ſemper in praxi copia ſufficienti, aut ſatis opportune adhibeantur, nec mei eſt, nec hujus loci inquirere.

Hæc proximo hyeme de igne meditatus ſum: ſed alia tunc temporis impediverunt ſtudia, ut cogitationes meas aut perſequi, aut etiam colligere, potuerim; & nunc mihi in alias regiones properanti, & tempus & animus deſunt. Liceat igitur finem imponere operi, quod multum ſane auctori ſuo tædii creavit. Nam & experimentorum capiendorum, imo & quandoque bonorum auctorum, ſed ante omnia temporis his rebus impendendi defectus, me impulit, ut, fere antequam ei manus impoſuiſſem, operis tæderet. Si ergo aut ſermo, aut materia aut ordo alicui minus placuerit, ſciat is etiam illos nec placuiſſe auctori. De ſtylo

ſtylo autem atque ordine minime ſum ſollicitus, quanquam hi quoque alias non ita inconditi fuiſſent. Sed de argumentis conficiendis, & præcipue experimentis probandis maxima mihi fuit cura. Hæc autem ex probatiſſimis hauſi auctoribus; inter hos eminent BOERHAAVIUS, MUSSCHENBROEKIUS, & MARCHIONISSA DE CHATELET, ſi autem eorum me fefellerunt experimenta, alios quoque antea fefellerunt. Vellem equidem mihi fuiſſe datam occaſionem illa videndi, quæ jam meditatur ALLAMANDUS noſter, rerum phyſicarum acutiſſimus obſervator; ſed quoniam hoc non ſinunt negotia mea, rudes has qualeſcunque lineas, ut lector accipiat, oro. Sane non ſperare poſſum, hanc in his pagellis propoſitam ſententiam, doctorum approbationem plenariam conſecuturam; ſi autem hæc aliquantulum tantum ad veritatem accedere reperiatur, promitto me deinceps operam daturum, ut aliquando ornatior & accuratior prodeat, & ſimul alias, quæ nunc evolvo, cogitationes, cum illis forſan, quæ jam meditata memoriæ meæ negligentia exciderunt, literati orbis judicio ſubmiſſurum. Quod ſupereſt, cum nunquam hæc tam cruda in lucem edidiſſem, niſi ut ſanctis hujus Academiæ legibus obedirem; neminem a milite coacto, quæ a voluntario præſtari poſſunt, expectare debere puto. Faveas igitur, Lector Benevole, & Vale.

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